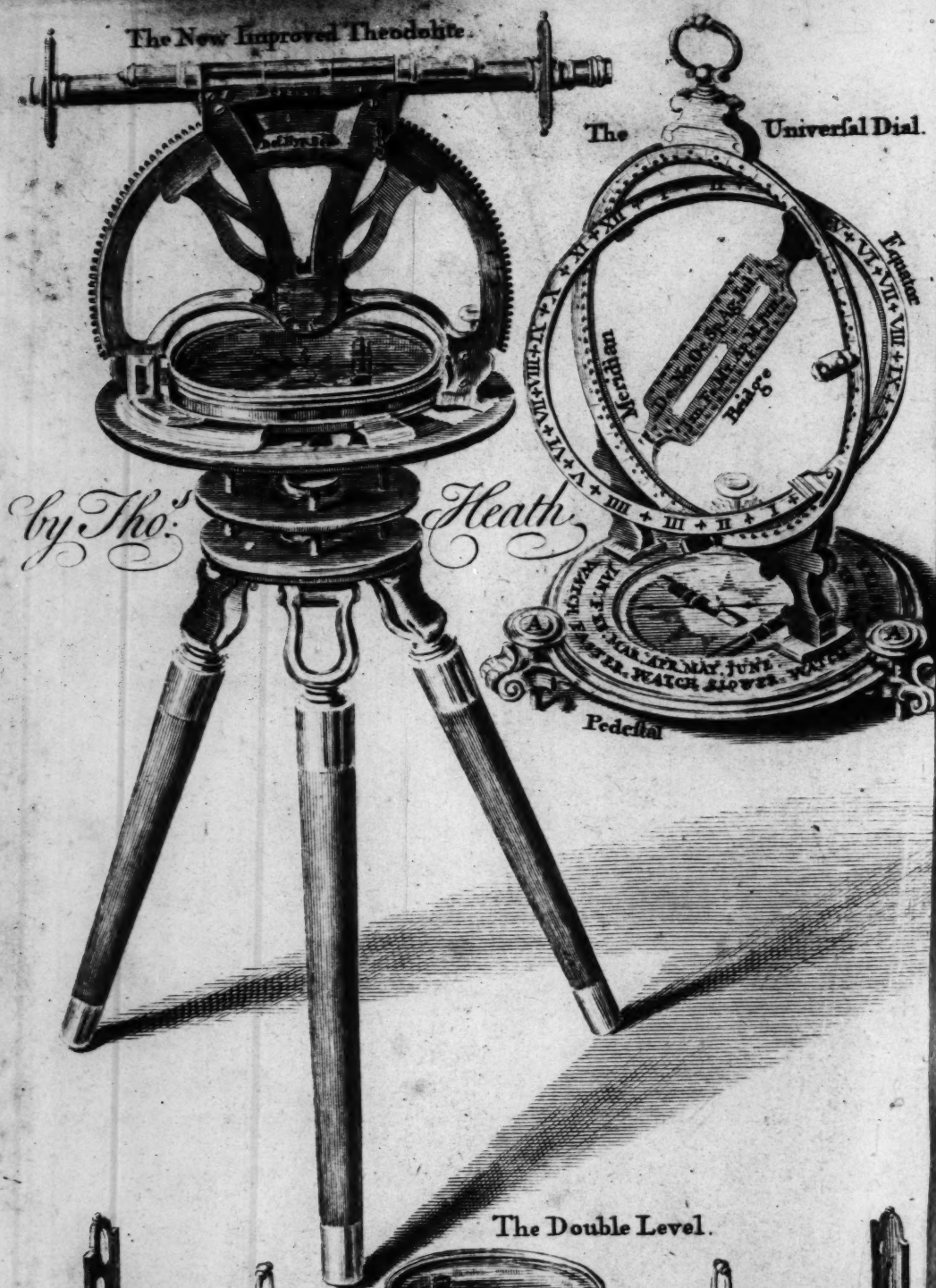
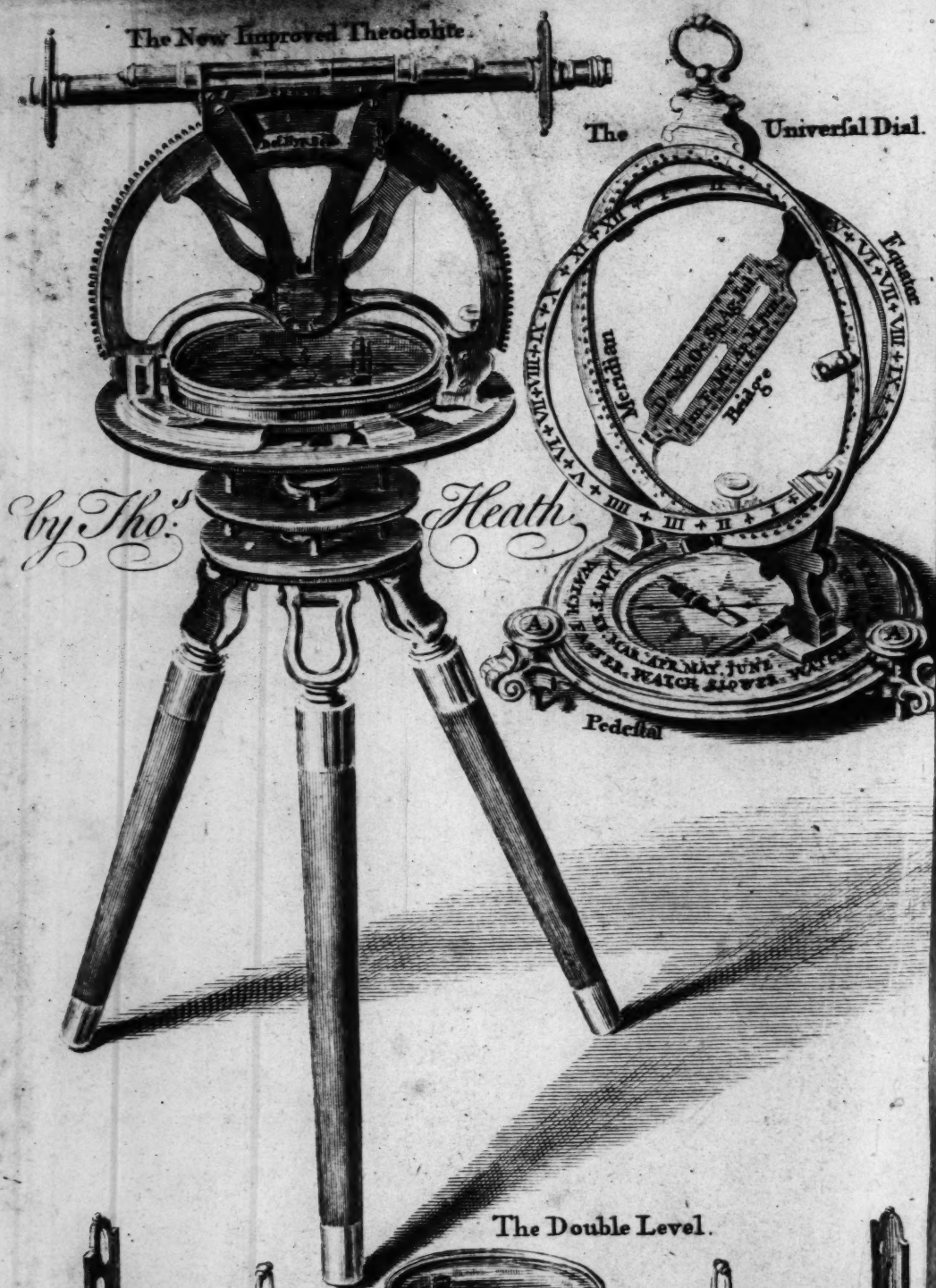




Mathematical Instruments
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THE
PRACTICAL SURVEYOR.

CONTAINING

The Most Approved METHODS
FOR

Surveying of LANDS and WATERS,

By the several

INSTRUMENTS NOW IN USE:

Particularly Exemplified with

The Common and New Theodolites,

AND ALSO

How to Plot and Cast up such Surveys, with the
Manner of Adorning the MAPS thereof.

To which are added,

Some Uses of the New Theodolite, *viz.*

In Drawing the Perspective Appearance of Buildings, &c.

In Levelling, for the Conducting of Water, and

In Taking the Dimensions of standing Timber.

Together with the Description and Use of

An Improved SLIDING-RULE for TIMBER, &c.

AN UNIVERSAL DIAL,

A MEASURING WHEEL, and

The PANTOGRAPHER, for Copying of Drawings.

First Published in Part,

By JOHN HAMMOND;

Since Enlarged,

By SAMUEL WARNER;

And now Revised, Corrected, and greatly Augmented.

The FOURTH EDITION.

L O N D O N:

Printed for HEATH and WING, Mathematical-Instrument-
Makers, at the Hercules and Globe, near Exeter-Exchange
in the Strand. M,DCC,LXV.

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T H E

P R E F A C E.

IN the following Treatise is contained the whole business of Land surveying, in the manner as is now practised by the most experienced artists; together with such problems and observations as are really necessary: And herein the subject is treated of in such a plain, tho' concise manner, that the most common capacity, with a very little reflection, will readily conceive the whole; especially if he has the instruments before him while he reads of their use: And although a great part of this work may be like what has been delivered by other writers, yet there is not one article relative to practice, but what the authors have drawn from their own experience.

The reader will here find, after some few introductory problems, a very particular and exact description of the several instruments used in surveying, and a just comparison of them together; particularly the various sorts of Theodolites: With due directions and cautions in their management, according to their several kinds, in order to prevent errors and mistakes, as well in the taking observations, and correcting them on the spot, as in plotting and laying them down in the draught.

Also two very large examples, being parts of actual surveys, containing most of the varieties that can happen in the practice of this art; the one performed by the common Theodolite, the other by the

new improved Theodolite : The manner of keeping the field-book in a distinct and clear method is here shewn ; how the observations and measures are to be plotted, and the contents of the several inclosures and pieces cast up : Also in the course of these two examples, and other parts of the work, there will be met with, every caution and direction that can any way contribute towards the ready dispatch and accuracy of the practitioner, not only with regard to the field work and plotting, but also in the drawing, colouring, and ornamenting of the map.

The new improved Theodolite is herein explained in its parts and use ; also its application to water levelling, taking of heights, and drawing in perspective, are distinctly and clearly treated of.

In the account of the Measuring-Wheel, Universal-dial, and Pantographer, the reader will see some particulars very useful and interesting ; but, as there is annexed a copious table of contents, it will be needless in this place to insist further on any of the articles contained therein.

The major part of this work was originally composed by that ingenious artist Mr. SAM. CUNN ; but for some reasons he let it appear under the name of JOHN HAMMOND, who was a clerk to his friend Mr. CHARLES BRENT. The second edition of this book was under the care of Mr. SAM. WARNER, a person well known for his skill in the business of surveying ; he added an appendix, containing a more particular description of the Improved Theodolite, with a new method of using it in taking observations in the field ; whereby an error may be more readily discovered and prevented than by any other way hitherto used ; with an example of the field-book of part of an actual survey taken thereby. Likewise a full explanation of the manner of laying down those observations from one center, so as to avoid the faults which arise from protracting angle by angle. As also how to
reduce

reduce irregular figures to triangles, with the application thereof in the casting up the contents of the fore-mentioned example. This appendix is now put into the body of the work, part being in Section I, and of the rest is composed the VIIIth Section. In the present edition, the former order of the subjects are varied, the reviser thinking the order they now appear in to be better: But besides this change, there are a very considerable variety of corrections, alterations, and additions; for the XIVth and XVIth Sections are not only added, but there are introduced into the work, many articles not in the former editions, and which were now thought very necessary to be communicated: Notwithstanding which, the bulk of this book is not increased above the former; tho' the present contains near three sheets of matter more than was in the last; which has been effected by making the page both broader and longer. Also the figures which in the former impressions were in four small plates, indifferently designed, and as ill referred to, are in this brought into one plate, and rendered more useful.

It may be proper to observe, that some of the notions in Section XIV were drawn from a little book of Martin Master, published in 1661: And part of the XVIth Section, is a translation from a French piece published by C. Langlois, an engineer to the French King, who pretends to no more than to have perfected an instrument of this kind already known; and, indeed, among the instruments of Sir Jonas Moore, such a one was found, but somewhat more antique and inconvenient than that which is now proposed: But M. Langlois not having given a table of the lengths of the several divisions from their respective centers, nor how they are to be found, it was thought proper to add these articles to compleat the account of the Pantographer.

Feb 18,
1749-50

J. R.
Note,

Note, The ensuing directions having been omitted in their proper places, it was thought convenient to annex them in this place.

In the beginning of the field-book it will be proper to write some such title as the following —

The Field-book, containing observations and dimensions taken in the survey of the manor of — in the parish of — in the county of —; belonging to —: Surveyed in the months of — in the year — by — and the following assistants, viz.
A. B. of the parish of — labourer.
C. D. —
&c.

Specifying their names, places of abode and occupation; and at the beginning of each day, write the day's name, day of the month and hour; also at the end of each day's work write the hour; and, if there should be occasion to change any of the assistants, or have new ones, let this be also inserted, with the day: For such observations may be of service, in case the surveyor should, on any account relating to the premises, be called on to give his testimony.

In drawing out the Terrier of a survey, a disposition, somewhat like the following, may be found convenient. In six columns, titled No, Kind, Names, Proprietors, Tenants, Quantity; write

1st, The number referred to in the map, if the several pieces therein are numbered.

2d, The kind, whether arable, pasture, meadow, wood, garden, houses, yards, water, &c.

3d, The name that the piece is known by.

4th, The name of the lord of the manor, or other person, to whom the piece belongs, whether in fee-simple or copy-hold.

5th, The name of the tenant who rents, or occupies the piece.

6th, The quantity that piece contains, in acres, rods, and poles.

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T H E

Practical Surveyor.



S E C T. I.

Of MENSURATION *in general, with the most*
necessary GEOMETRICAL PROBLEMS.



O Measure, in the general sense that Geometricians use the word, is, to assume any certain quantity; and express the proportion which other similar quantities bear thereto: But in the common acceptation, to Measure, is, to apply some certain known quantity pitched upon for a standard, and thereby to determine the precise extent, quantity or capacity of any thing of the same kind. Thus:

The measure of a line is found by applying the lineal Inch, Foot, Yard, Pole, &c. to that line, in

B

order

order to discover its length; the doing of which is called Longimetry.

The Measure of a superficies is obtained by the application of the superficial or square Inch, Foot, Yard, Pole, Acre, &c. thereby to determine its Area or Content; the method of doing which is called Plainimetry, whereof Surveying of land is a part; and of this the following pages chiefly treat.

The Measure of a solid is had by comparing it with the solid or cubic Inch, Foot, Yard, Gallon, &c. thereby to find its capacity or solid content, which is called Stereometry, and comprehends the measuring of Timber, Stone, &c.

Now, though it cannot be supposed that any Person, who is wholly ignorant of the first principles of Geometry, should expect to become a compleat Surveyor by barely reading this Book, whence it might seem altogether unnecessary to insert the common Definitions and Problems; yet, in order to refresh the reader's memory, when other Books are not at hand, it was thought not improper to lay down some few of the most popular Problems; and such are those that follow.

P R O B.

P R O B. I.

Upon a given right line, to erect another right line, which shall be perpendicular to the right line given.

THE right line given is AB (Fig. 1.) upon which, from the point E it is required to erect the perpendicular EH.

Opening your Compasses at pleasure to any convenient distance, place one foot in the assigned point E, and with the other make the marks C and D, equi-distant on each side the given point E. Then opening your Compasses again to any other convenient distance, wider than the former, place one foot in C, and with the other describe the Arch GG; also (the Compasses remaining at the same distance) place one foot in the point D, and with the other describe the Arch FF: Then from the point H, where these two Arches intersect or cut each other, draw the right line HE, and it will be a Perpendicular to the given right line AB; which was the thing required to be done.

P R O B. II.

To erect a perpendicular upon the end of a right line given.

LET AB (Fig. 2.) be a right line given, and from the end thereof, at B, let it be required to erect the Perpendicular BF.

First, Your compasses being opened at any convenient Distance, place one foot in B, and with the other make the mark C; the Compass point resting in C, with the other foot make the mark D, in the given line AB; lay a Ruler from D to C, and draw the line DE, making CE equal to CD. Lastly, from B, through E, draw the line BF, which will be the Perpendicular required.

P R O B. III.

To divide a given right line into two equal Parts.

LET CB (Fig. 3.) be a right line given, to be divided into two equal Parts.

From the extremes B and C, with any distance greater than half the given line, describe the arches, above and below, cutting one another in the points D and F : Draw DF, and it will divide AB into two equal parts in H, as required.

P R O B. IV.

To let fall a Perpendicular from any Point assigned, upon a right line given.

LET the point given (Fig. 4.) be C, from which point it is required to draw a right line, which shall be perpendicular to the given right line AB.

First, From the given point C, to the line AB, draw an occult line at pleasure, as CE, which divide into two equal parts in the point D : Then placing one foot of the compasses on the point D, with the distance DC, describe the Semicircle CFE, cutting the given line AB in the point F. Lastly, from the point C, draw the right line CF, and it shall be the perpendicular to the given line AB, which was required.

P R O B.

P R O B. V.

To make an angle equal to an angle given.

LET the angle given be ACB (Fig. 5.) and let it be required to make another angle equal thereunto.

First, Draw the line EF at pleasure; then on the angular point C, as a center, with any convenient distance describe the arc AB, between the legs of the angle given; also upon the point F, with the same distance describe the arc DE: Then take with your compasses the distance AB, and set the same distance from E to D. Lastly, Draw the line FD, so shall the angle DFE be equal to the given angle ACB.

P R O B. VI.

At a given Distance, to draw a right line parallel to a right line given.

LET the line given be AB, (Fig. 6.) unto which it is required to draw another right line parallel, at the distance MN.

First, Open your compasses to the distance MN, then placing one foot in A, with the other describe the arc C; also place one foot in B, and with the other describe the arc D. Lastly, Draw the line CD, so that it may only touch the arcs C and D; so shall the line CD be parallel to the line AB, and at the distance MN, as was required.

P R O B. VII.

A right line being given, to draw another right line parallel thereunto, which shall also pass through a point assigned.

LET AB (Fig. 7.) be a line given, and let it be required to draw another line parallel thereunto, which shall pass through the given point C.

First, Take with your compasses the distance from A to C, and placing one foot thereof in B, with the other describe the Arc DE; then take in your compasses the distance AB, and placing one foot in the point C, with the other describe the Arc FH, crossing the former Arc DE in the point H. Lastly, Draw the line CH, and it shall be parallel to AB.

These two last PROBLEMS may be more easily performed by a parallel Ruler.

P R O B. VIII.

To divide a given right line into any number of equal parts.

LET AB (Fig. 8.) be a right line given, and let it be required to divide the same into five equal parts.

First, from the end A of the given line, draw the line AC, making any angle; then from the other end B of the given line, draw the line BD parallel to AC, (or make the angle ABD equal to the angle CAB) then upon the lines AC and BD, set off any four equal parts (which is one less than the number of parts into which the line is to be divided) on each line, as 1, 2, 3, 4; then draw lines from 1 to 4, from 2 to 3, from 3 to 2, and from 4 to 1, which lines, crossing the given line AB, shall divide it into five equal parts, as was required.

P R O B,

P R O B. IX.

Any three right lines being given, provided the two shortest taken together be longer than the third, to make thereof a triangle.

LET it be required to make a Triangle of the three lines C, B, and A, (Fig. 9.) the two shortest whereof, viz. C and B taken together, are longer than the third line A.

First, Draw the line DE equal to the given line B, then take with your compasses the line A, and setting one foot in E, with the other describe the Arch HG; also take the given line C in your compasses, and placing one foot in D, with the other describe the Arch KF, cutting the former Arch HG in the point O: Lastly, if from the point O, you draw the lines OE and OD, there will be formed the Triangle ODE, whose sides shall be equal to the three given lines A, B, C.

In like manner, a Triangle *lmn* may be made equal to another given Triangle LMN. See Fig. 10.

Also any rectilineal figure *abcdefg*, is made equal to any other rectilineal Figure ABCDEFG, by making the Triangles *abg*, *bgf*, *bfe*, *bce*, *ced*, respectively equal to the Triangles ABG, BGF, BFE, BCE, CED. See Fig. 11.

P R O B. X.*

To reduce any irregular Figure into a Triangle.

By this Problem the content of any irregular piece of land may be cast up much sooner and more accurately than by the common method of dividing it into Trapezia and Triangles.

THE practice hereof depends wholly on the 37th Prop. of the first Book of EUCLID, where it is demonstrated, that Triangles standing on the same base, and being between the same parallels are equal one to the other.

E X A M P L E I.

Let it be required to reduce the Trapezium ABCD, Fig. 12. into a Triangle, having its Vertex at the Angle A.

Produce the base BC, and draw the diagonal AC, thro' D draw DE parallel to AC, till it meet BC in E, join AE and ABE will be the Triangle required.

Fig. 13. shews how in like manner to reduce a Trapezium having a re-entring angle.

E X A M P L E II.

Let it be required to reduce the Trapezium ABCD, Fig. 14. to a Triangle whose vertex shall be at the point E in one of the sides AD.

Join BE and CF, draw AF parallel to BE, and DG parallel to CE, till they meet the base BC produced in F and G, draw the lines EF and EG, and the triangle FEG will be equal to the Trapezium given.

* This Problem and its Examples, are a Part of Mr. Warner's Appendix to the last Impression of this Work.

EXAMPLE III.

Let it be required to reduce the Pentagon ABCDE, Fig. 15, to a Triangle, having its vertex at the Angle A.

Produce the base CD both ways, and draw the Diagonals AC, AD: Through B draw BF parallel to AC to cut CD in F, and through E draw EG parallel to AD to cut CD in G, join AF and AG, and AFG will be the Triangle sought.

EXAMPLE IV.

Let it be required to make a triangle equal to the irregular Hexagon ABCDEF, and let the side AB be one side of the triangle, Fig. 16.

Produce the side DE, join AE, and parallel thereto through F draw FH to meet DE in H; join BD, and parallel thereto draw CG to meet DE in G; by B and G draw out a right line; join AG, and parallel thereto through H draw HI to meet BG produced in I, draw AI, and ABI will be the triangle required.

EXAMPLE V.

To reduce any right-lined Figure given into a triangle; as suppose the seven-sided Figure ABCDEFG, Fig. 17.

First draw BD, and its parallel CK; then if BK be drawn, it will cut off from the Figure the triangle DKS, and will take in the triangle BCS equal thereto, and the side BK will supply the use of the two sides BC and CD. Also, draw GE, and its parallel FL; then if GL be drawn, it will cut off from the figure the triangle LRE, and take in the triangle GRF equal thereto, and the side GL will supply the use of the other two sides GF and FE,

FE, and the whole Plot ABCDEFG, consisting of seven sides, is reduced to the five-sided figure ABKLG, yet still retaining the same quantity. Now to reduce this plot into a triangle, work in all respects as in the Third Example. First, produce the base both ways, then draw the lines AK and AL; and parallel to them the lines BH and GM, cutting DE extended in H and M. Lastly, draw the lines AH, AM, and they will constitute the triangle AHM equal to the right-lined figure given.

In like manner may any other irregular figure of ever so many sides be reduced to a triangle, and that very readily by using a parallel Ruler, whereby we avoid drawing the unnecessary lines, only marking their intersections on the base. Thus in Fig. 18. lay the edge of a Parallel Ruler to the points B and D, then open the Ruler till the same edge cuts the point C, and mark where it intersects the base DE at k; lay the Ruler again to the points k and A, transfer it to B, and mark its intersection on the base at h; then draw A h, which will be one side of the triangle sought. Again, laying the Ruler to E and G, transfer it to F, and mark the intersection on the base at l, lay the Ruler to l and A, and mark where its parallel edge by G intersects the base prolonged at m. Lastly, draw A m, and the triangle A h m will be equal to the seven-sided figure as was required,



S E C T. II.

Of INSTRUMENTS used in surveying Land.

INSTRUMENTS used in surveying are either to measure, or lay down the lengths of lines, or their positions.

The most proper instruments for measuring lengths, in towns, streets, or any other buildings, are 5 feet and 10 feet rods, and a chain of 50 feet long; for fields and woods, a chain, which from its contriver, is usually called GUNTER'S Chain, and is in length 66 feet, or 4 poles, consisting of 100 links, each containing 7 inches and $\frac{9}{10}$; and rod called an OFFSET-STAFF, whose length is equal to $\frac{1}{10}$ part of the chain; that is, 10 links, or 6 feet 7 inches and $\frac{2}{10}$ tho' sometimes this rod is 15 links in length, or 9 feet 10 inches and $\frac{8}{10}$.

The wheel is used with most advantage in measuring of roads.

The instruments used for taking the positions of lines, are of two kinds.

With some we take the position of a line by the angle which that line makes with the meridian, using a box and needle; as with the Theodolite, the Semicircle, the Circumferentor, the Plain-Table, the Perambulator, the Peractor, &c. and this is usually called the *Bearing of the Line*.

With others we take the position by the angle that the line makes with any other given line in position; as with the limb of the Theodolite, the limb
of

of the Semicircle, the frame of the Plain-Table, the Bevel, the Chain, or Rods.

All other instruments either differ from these only in their names, or else are contained in them.

But with some of these instruments, very conveniently we take the position in both cases, at one observation; as with the Theodolite, the Semicircle, or the Plain-Table.

With some of these instruments we take the angle itself, as with the Bevel, or with the Plain-Table covered with a sheet of paper; and with others, we express the relative quantity of that angle by numbers. So when we use the chain, we express the angle by Sextants, Links, and tenth parts of a Link; when we use Rods, we express it by Sextants, and centesimal parts of a Rod, and when we use other instruments, we express the angles by degrees and minutes.

We may also observe, that of Theodolites and Semicircles there are various kinds; in some the Box and Needle is fixed to the Plate, in others to the Index. And the working with each of these varies according to the manner of their numbering.

As for Roads, the wheel with its indices, shewing the distance, and its box and needle with sights shewing its bearing or position in respect of the Meridian, is an instrument speedy and sufficiently exact; provided we reject the breadth of the road, and only regard the bearing and length.

Lastly

Lastly, Instruments for plotting are a scale decimally divided the whole length, close to both the edges; and at every tenth division numbered 0, 1, 2, 3, 4, &c. denoting chains; the Numbering so ordered, that we may count either from the Right to the Left, or from the Left to the Right; and a Protractor always to be divided, numbered, and fitted according to your instrument.

Thus, all Circumferentors, (either absolutely such, or only used as such, *viz.* when contained in the Theodolite, Semicircle, or Plain-Table) let the numbers in the Protractor increase contrary to those in the box; but when the box and needle take the bearing, as the Peractor or Perambulator doth, the numbers of the Protractor must increase as those in the box.

And for the limbs of all Theodolites, Semircles, and Plain Tables if the circuit be made $\left\{ \begin{array}{l} \text{according} \\ \text{contrary} \end{array} \right\}$ to the numbers on the limb, the numbers of the Protractor most conveniently increase the $\left\{ \begin{array}{l} \text{contrary} \\ \text{same} \end{array} \right\}$ way with the numbers on the limb of the instrument, and this supposing the eye in the center.





SECT. III.

To observe the Position of a Line by any of the preceding Instruments.

I. By the Circumferentor.

THE box of the Circumferentor is divided into 360 degrees, and numbered in four quarters, from the North and South both to the East and West, by the figures 10, 20, 30, 40, 50, 60, 70, 80, 90; but these divisions are also numbered from the North towards the East or West, all round, till they end at the North again; by the figures 10, 20, 30, 40, 50, 60, 70, 80, 90, 100; and so on to 360. Of these two ways of numbering, the latter is properly the Circumferentor, and the former the traversing Quadrants or quarters.

Now, if it be required to observe the bearing of the line AB (Fig. 19.) the instrument standing at A; the flower-de-luce in the box being towards you, direct the sights to B; and the South end of the needle will point at 207 degrees in the Circumferentor, and at S. W. 27, in the traversing Quadrants.

And if you were going round the field, and so next to observe the bearing of the line BC; at B turn the index about, the flower-de-luce being towards you, till thro' the sights you see the hair cut C: Then will the South end of the needle point at

III, in the Circumferentor, (which is the bearing always counted from the North, and in these Examples from the North to the Eastward) and at S. E. 69 in the traversing Quadrants, which is the bearing always counted from the North or South towards the East or West. Here we may note, that the bearing taken with the Circumferentor may be any number of degrees not exceeding 360, but that with the traversing Quadrants never exceeds ninety degrees.

When you suspect the needle does not play well, direct the Index to your mark, and note, in a waste piece of paper, the degrees pointed at by the needle; then with a clean knife, or a key, or any other polished bit of Steel, which has touched a Loadstone, move the needle, by applying it to the Box, and when it has settled again, examine what degree it then points at, your index being still directed to the preceeding mark; and if the degrees are the same, they may be entered into the Field-book; but if not, the cap and pin must be cleansed with some brown paper, and a little puttey or whiting, and thereby freed of such dust or dampness as hath gotten to it; if, after all, the needle doth not play freely, screw in a new pin, or use another needle, or do both. These necessities every Surveyor ought to have in his pocket while he is in the field.

If you suspect an error in the bearing of any line already taken, arising from the needle's being acted on by some hidden magnetic power, or from your own mistake in observing the degrees pointed at; the doubt may be cleared, and the error corrected at the next station; thus,

Having come to B (Fig. 19.) the flower-de-luce being from you, look back to A, and then will the South end of the needle point at 207 degrees in
the

the Circumferentor and at S. W. 27 degrees in the traversing Quadrants ; just as it did at A.

Lastly, If you have no reason to suspect the needle, and it is most convenient to plot by it, the speediest way is to place the instrument only at every other angle, and there to take the bearing of the two lines which form that angle.

So, if you would observe the bearings of the lines of fig. 19, first place the instrument at B, and with the flower-de-luce from you, direct the sight back to A, so the South end of the needle will point at 207 degrees in the Circumferentor, and at S. W. 27 degrees in the traversing Quadrants, which is the bearing of A B ; then with the flower-de-luce next you, direct the sights to C, so the South end of the needle will point at 111 degrees in the Circumferentor, and at S. E. 69 degrees in the traversing Quadrants, which is the bearing of BC.

Now place the instrument at D, the flower-de-luce being from you, direct the sights back to C, so the South end of the needle will point at 44 deg. 30 min. in the Circumferentor, and at N. E. 44 deg. 30 min. in the traversing Quadrants, which is the bearing of CD ; and directing the sights to E, the flower-de-luce being towards you, the South end of the needle will point at 102 deg. 15 min. in the Circumferentor, and at S. E. 47 deg. 45 min. in the traversing Quadrants.

In like manner work at F, &c. always keeping the flower-de-luce from you when you look backwards, and towards you when you look forwards, so will the South end of the needle point at the degrees of the bearing in both cases.

*To protract any line whose bearing is taken by
the Circumferentor.*

FIRST, draw lines parallel to one another quite thro' the designed draught, at distances not exceeding the breadth of the diametrical part of your Protractor, as in fig. 19. and mark them with N. and S. for north and south; then lay the center of the Protractor on A, the point given representing the station A in the field, and, by help of the divisions continued beyond the ends of the diameter of the Protractor, lay the diameter parallel to those north and south lines; and if the Protractor be only a Semicircle, lay the beginning of the numbering northwards, when the degrees are fewer than 180, but southwards when more: the Protractor being thus placed, make a mark close to the limb against 207, the degrees of the bearing, and thro' it draw the line AB; and so will AB have a bearing like to that, which you observed the line AB to have in the field. In like manner you may lay down the bearing of any other line, as BC; if you observe to lay the beginning of the numbering northwards, when the degrees are less than 180, and southwards when more: but if the Protractor be a whole circle, there will be no occasion for turning the beginning of the numbers, which may always be northwards.

And if you would lay down the bearing of any line AB, fig. 19. from any assigned point A. with the traversing quadrants; after you have drawn north and south lines as before, the north being upwards, write east on the right hand side of the map, and west on the left. Now lay the center of the Protractor and diameter as before shewn; save that instead of observing the number of the degrees, you turn the limb of the Protractor east-ward,

ward, when the bearing is N. E. or S. E. and westward, when it is N. W. or S. W.

The Protractor being thus placed, against S. W. 27. make a mark, and thro' it draw the line AB, and so will AB have a bearing like to that which AB was observed to have in the field. In like manner you may lay down the bearing of any other line.

II. *To observe with a Theodolite, both by the Limb, and by the Box and Needle.*

BEFORE you engage in a survey, you ought to consider the numbering of your instrument; thus, when the eye is conceived to be placed in the center, consider whether the numbers increase from the left to the right; or from the right to the left; or, according to the farmer's familiar phrase, whether the numbers increase with or against the sun's motion.

And then observe, that with a Theodolite, whose box is fixed to the plate, the circuit is most conveniently made with the increasing of the numbers; and the fixed sights shall always be directed to the next station, and the index to the last. But when the box is fixed to the index, 'tis best to go round contrary to the order of the numbers; and then the fixed sights are to be directed to the last station, and the index to the next.

And if the beginning of the degrees are kept towards you when the fixed sights are directed, and the flower-de-luce towards you when the index is directed; the degrees cut by the end of the index which is next you, are those which measure the angle; and the degrees pointed at in the box by the south end of the needle, give the bearing of the next length. And this bearing will be, in all respects, the same with that taken by the Circumferentor;

ferentor ; provided that the box be divided and numbered like that of the Circumferentor.

This double observation is of great use to the surveyor ; for hereby he may either plot by the angle, or the bearing, or by both, as he shall find most convenient ; and also, may prove his observation before he moves the instrument. For, of the numbers expressing the bearing of the lines forming any angle, if the lesser be subtracted from the greater, and the remainder be increased by 180 degrees when less than 180, or, if greater than 180, is diminished by 180 ; the result in either case will give the angle itself, or its supplement to 360 degrees.

When a Theodolite is used with a box fixed to the plate, and the numbers in the box increase the same way with the numbers on the plate ; or, which comes to the same, with the box fixed to the index, and the numbers therein increase the contrary way with the numbers on the plate (most Theodolites being made one of these ways, or should be so to be most convenient) ; then a Protractor being numbered contrary to the numbers in the box, will be fitted to lay down the plan, either according to the angles taken by the limb, or by the bearing taken with the needle, or by both together, in order to prove the truth of each other : and then also may the truth of the angle or bearing be proved, before the instrument is moved from the station by either of the two following rules.

If to the present bearing be added 180 degrees, and from the sum you subtract the last bearing ; then the remainder will be the present angle.

And if to the present angle you add the last bearing, and from the sum subtract 180 ; then will the remainder be the present bearing.

But if the degrees to be subtracted are more than those from which they are to be subtracted ; the latter must be increased by 360, and then subtract.

And if the remainder be more than 360, then abate 360, and the result gives the degrees required.

So, with a Theodolite that hath the box fixed to the index, and the eye being conceived in the center, the numbers on the plate increase from the left to the right, but those in the box the contrary way, and so most proper to work against the sun : if you would take the bearings of the lines of fig. 19. beginning from any assigned angle, suppose A ; then your instrument being planted at A, direct the index to the next station at B, and the south end of the needle will point at 207 degrees in the Circumferentor. And for the following angles and bearings, when the

instrument is $\left\{ \begin{array}{c} B \\ C \\ D \\ E \\ F \\ G \end{array} \right\}$ direct the fix'd sights to $\left\{ \begin{array}{c} A \\ B \\ C \\ D \\ E \\ F \end{array} \right\}$

and there screw the instrument fast ; then direct the index to $\left\{ \begin{array}{c} C \\ D \\ E \\ F \\ G \\ A \end{array} \right\}$

and the end of the index next your eye will cut on the limb the angles $\left\{ \begin{array}{cc} 84. & 00' \\ 113. & 30' \\ 237. & 45' \\ 49. & 35' \\ 102. & 40' \\ 234. & 00' \end{array} \right\}$

and

and the south end of the needle will, as in the Circumferentor, point at

°	'
111.	00
44.	30
102.	15
331.	50
254.	30
308.	30

And with a Theodolite, that hath the box fixed to the index, and the numbers of the plate contrary to those of the box, while the eye is conceived placed in the center, increase from the right to the left; and so most proper to work according to the sun's motion; if you would take the angles and the bearings of the lines of Fig. 19. and begin from any assigned angle, suppose A; then your instrument being planted at A, direct the index to the next station G, and the south end of the needle will point at $231^{\circ} 30'$ in the Circumferentor. And for all the following angles and bearings, when the

instrument is planted at	$\left\{ \begin{array}{c} G \\ F \\ E \\ D \\ C \\ B \end{array} \right\}$	direct the fixed sights to	$\left\{ \begin{array}{c} A \\ G \\ F \\ E \\ D \\ C \end{array} \right\}$
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and there screw the instrument fast; then direct the index to - - -	$\left\{ \begin{array}{c} F \\ E \\ D \\ C \\ B \\ A \end{array} \right\}$
--	--

and the end of the index next the eye will cut on the limb the angle

°	'
234.	00
102.	40
49.	35
237.	45
113.	30
84.	00

and the south end of the needle, as in
the Circumferentor, will point to
the bearing - - - - -

°	'
285.	30
208.	10
77.	45
135.	30
69.	00
333.	00

But with the Theodolite, that hath the box fixed to the plate, and the numbers on the plate as well as those in the box (the eye being placed in the center) increase from the right to the left, and therefore most proper to work contrary to the sun's motion; if you would take the angles and the bearings of the lines of Fig. 19. and begin at an assigned angle A; then your instrument being planted at A, direct the fixed sights to B, and the south end of the needle will point at $207^{\circ} 00'$, as in the Circumferentor, and as in the first example. And for all the following angles and bearings, when the in-

ment is planted at $\left\{ \begin{matrix} B \\ C \\ D \\ E \\ F \\ G \end{matrix} \right\}$ direct the fixed sights to $\left\{ \begin{matrix} C \\ D \\ E \\ F \\ G \\ A \end{matrix} \right\}$

then screw the instrument fast, and direct the index to - - - - - $\left\{ \begin{matrix} A \\ B \\ C \\ D \\ E \\ F \end{matrix} \right\}$

so will the end of the index next the eye cut on the limb the angle

°	'
84.	00
113.	30
237.	45
49.	35
102.	40
234.	00

and

and the south end of the needle, as
in the Circumferentor, will point
at the bearings - - - - -

	°	'
III:	00	
44.	30	
102.	15	
331.	50	
254.	30	
308.	30	

both as in the First example.

Also with a Theodolite, that hath the box fixed to the plate, and the numbers on the plate, as well as those in the box, the eye placed in the center, increase from the left to the right, and therefore most proper to work according to the sun's motion; if you would take the angles and the bearings of the lines Fig. 19. and begin at an assigned angle at A, direct the fixed sights to G, and the south end of the needle will point at $231^{\circ} 30'$ as in the second example. And for all the following angles and bearings, when

the instrument is planted at $\left\{ \begin{array}{c} G \\ F \\ E \\ D \\ C \\ B \end{array} \right\}$ direct the fixed sights to $\left\{ \begin{array}{c} F \\ E \\ D \\ C \\ B \\ A \end{array} \right\}$

then screw the instrument fast, and direct the index to - - - - - $\left\{ \begin{array}{c} A \\ G \\ F \\ E \\ D \\ C \end{array} \right\}$

and so will the end of the index, next the eye, cut on the limb, the angle $\left\{ \begin{array}{c} 234. 00 \\ 102. 40 \\ 49. 35 \\ 237. 45 \\ 113. 30 \\ 84. 00 \end{array} \right\}$

and the south end of the needle, as in
 the Circumferentor, will point at
 the bearings. - - - - -

285.	30
208.	10
77.	45
135.	30
69.	00
333.	00

both as in the second example.

With either of these four instruments, the angles and the bearings of the lines are taken, at once setting the index, as easily and expeditiously as the angle itself only; which evidently appears from the four preceding examples. And the truth of these observations may be readily proved by either of the rules already laid down.

For, the instrument being planted at B, in the first and third examples, if to $111^{\circ} 00'$ the bearing there taken, you add $180^{\circ} 00'$, and from the sum $291^{\circ} 00'$, take the last bearing $207^{\circ} 00'$, there will remain $84^{\circ} 00'$, which gives the angle taken at B, exactly as there observed; and proves the angle and these two bearings to have been truly observed.

In like manner, the instrument being planted at C, in the same examples; if to the bearing there taken, $44^{\circ} 30'$, you add $180^{\circ} 00'$, and from the sum $224^{\circ} 30'$, you subtract $111^{\circ} 00'$, the bearing taken at the last station; the remainder $113^{\circ} 30'$ gives the angle at C exactly as it was there observed; which proves that the angle, and also the last and present bearings are truly observed.

Also the instrument being planted at D; if to the bearing there taken $102^{\circ} 15'$, you add $180^{\circ} 00'$, and from the sum $282^{\circ} 15'$, take $44^{\circ} 30'$ the last bearing; the remainder $237^{\circ} 45'$ gives the angle at D, as there observed.

But the instrument being planted at E, if to the bearing there taken, $331^{\circ} 50'$ you add $180^{\circ} 00'$, and from the sum $511^{\circ} 50'$ you subtract $102^{\circ} 15'$
 the

the last bearing; the remainder $409^{\circ} 35'$ less'n'd by 360° , because greater than 360, gives $49^{\circ} 35'$, the angle at E. And so of all the rest.

And in like manner may the angles and bearings be compared in the second and fourth examples.

Or the angles and bearings may be compared by the second rule thus: The instrument being planted at B, if to $84^{\circ} 00'$, the present angle, you add $207^{\circ} 00'$, the last bearing, and from the sum $291^{\circ} 00'$ you take $180^{\circ} 00'$, the remainder $111^{\circ} 00'$, gives the present bearing, as observed.

The angles and bearings being truly taken, it remains to shew how

To plott, and therein to discover and correct an error before it is communicated to the following part of the work.

HAVING provided yourself with a Protractor, whose numbers increase contrary to those in the box, draw across your designed draught parallel lines, as in plotting observations taken with the Circumferentor.

Then having chose a convenient point to represent the first station, as at A; from thence, working by the first or third examples, lay down the bearing $207^{\circ} 00'$, and draw AB, as shewn in plotting from the Circumferentor. On the point B lay the center of the Protractor, and its diameter on the line AB produced both ways, if necessary, so that the beginning of the degrees may be towards the last station, if the angle be less than 180° , but the contrary way, if greater; and close to the edge of the Protractor make a mark against $84^{\circ} 00'$, the degrees of the angle B, and draw BC. Turn the Protractor about on its center, till the diameter be parallel to the meridians, the beginning of the degrees being towards the north, when the bearing is less

less than 180° ; but contrarywise, when more; and if the line BC cut the bearing $111^{\circ} 00'$ on the edge of the Protractor, that line is truly laid down; but not so, if it cut any where else.

But working according to the second and fourth examples, lay down the bearing $231^{\circ} 30'$, and draw AG: On the point G lay the center of the Protractor, as before shewn, its diameter coinciding with the line AG, and mark off the angle G, $234^{\circ} 0'$, draw GF: Turn the Protractor, as before, and if FG cut $285^{\circ} 30'$ on the Protractor's edge, the line is truly laid down.

In like manner, may any other angle be examin'd, and if found erroneous, the error may be corrected, before it is communicated to the following part of the work.

And we may observe, that, if the plot be laid down by the bearings of the lines, those bearings may be examined by measuring the angles as soon as plotted.

Though this method sufficiently recommends itself, both in respect to dispatch as well as accuracy; I do not expect it will be practised by any but the unprejudiced. For he who hath surveyed much land with a Circumferentor alone, or with a Semi-circle or Theodolite, without a needle, or with any other instrument, that doth not afford a double observation; he I say, hath not provided a check to his frailty, and will scarce forsake his old way, because he will not accuse himself.

There are two other ways to use the Theodolites, each equally exact with the former, but not so expeditious. One way is to take the bearing with the traversing quadrants; the other is to take the bearing with the degrees on the limb. But the angle is always taken as above.

If you would use the traversing quadrants, then the observing, the plotting, and the proof in plotting,

ting, are all as easily speedily, and exactly done as by the first method ; but the proof of the observation in the field, though equally true with the former, is neither so easily performed, nor so easily reduced to one single rule. But the person who is resolved to plot by the traversing Quadrants, had best take the observation both by the Quadrants and by the Circumferentor ; and then prove the observation in the field by the Circumferentor, and the plotting by the traversing Quadrants.

Lastly, If you would take the direction or bearing by the divisions on the limb with a Theodolite, whose box is fixed to the plate ; then (having taken the angle as before shewn) turn the instrument about till the north end of the needle point at 360 degrees in the box, and screw it fast ; direct the index to the next station, and the end next you will give on the limb the direction in degrees and minutes, as in the former examples.

But with a Theodolite, whose box is fixed to the index, if you would take the direction by the divisions on the limb ; then (after the angle is taken, as before shewn) direct the fixed sights to the next station, screw the instrument fast, and turn the index about till the north end of the needle point at 360 degrees in the box ; and then will the end of the index nearest to the south end of the needle cut on the limb the direction in degrees and minutes. But the Protractor to lay this bearing down, must be numbered contrary to the limb on the instrument.

The great advantage usually proposed by this last method, is, that the degrees on the limb are larger and more distinctly cut, and consequently more nearly estimated than those in the box. But consider that you can no better bring the needle to point at any one degree, than you can estimate its position in any other degree ; and that since we use the needle
all

all the objections made in one method are incident to the other; and then you may easily conclude, that the advantage is only imaginary.

Besides here we are obliged to take two observations, either of which take up as much time as the observation used in the former method; which renders it not fit for a practitioner.

Of the use of these Theodolites, I have one thing more to advertise, *viz.* to measure and cast up the content of one large single wood or common, where there are some scores of angles to be taken, the safest way is to cast, without plotting, by the help of the needle. And in this case I would take the directions both with the Circumferentor and the traversing Quadrants; and in the field prove the directions taken with the Circumferentor by the angles taken by the limb; and then, still in the field, prove both lengths and directions in calculating a traverse, by help of a traverse Table; and lastly, from this traverse (at leisure) deduce the true content.

But the traverse tables that are now extant, are but specimens of those which are fit for use; instruments are not sufficiently exact, and trigonometrical operations too laborious, and therefore this way of computation must be deferred, till some person who hath leisure and patience to serve the world, in calculating such a table, is resolved to do it*.

Of any one of the four Theodolites, which have the numbers on the box, contrary to those Theodolites before described, one or more inconvenience will always arise, use which of the three fore-mentioned methods you please.

It is true, the angle taken by the limb, is performed as shewn in the preceding rules; but since

* Here the author promises if he can procure such a table, as he hoped to do, to publish it with its uses in Practical Surveying and Navigation: But he being long since dead, that design has dropped.

it is not safe to work by the limb only, if you use the Circumferentor, as shewn in the first rule, you must either subtract the direction from 360 degrees, and enter the remainder, instead of the direction pointed at by the needle; or else use two Protractors, which will be troublesome, and also apt to cause mistakes by using the one for the other.

If you use the traversing Quadrants only, then indeed the use is in all respects the same with the preceding ones; but these, as I have already shewn, are not so expeditious as, nor more exact than the method first laid down.

If you will take the direction by the limb, and still make one Protractor plot both observations, you must direct your instrument twice, whereas by the first method laid down, it might be done at once.

Lastly, Of Theodolites those are best which have telescopes with plain sights on them, and so contrived that the Surveyor may at any time adjust any small accident, without coming to a workman; and that both of them may be elevated or depressed at least ten degrees; one of these telescopes, instead of the fixed sights, the other instead of the moveable ones, and as long a needle as will play well, with other the like conveniences, sufficiently known to a skilful instrument-maker.

III. *To observe with a Semicircle that hath a Box and Needle.*

A Semicircle is just half the Theodolite, and admits of just as many varieties; it is number'd on the limb to 180 degrees, and in arch concentric to this is denominated by the numbers 190, 200, 210, &c. to 360 standing under the former numbers 10, 20, 30, &c. Its use, in all respects (both to the plate and box) is the same with the Theodolite; save in this, that when the end of the index next the eye, falls off the plate, the degrees cut on the limb are to be taken from the further part of the index reckoned among the divisions of the inner circle, and will be always more than 180 degrees.

There are other ways of numbering and dividing (and perhaps without a box and needle) used in these instruments; but they are not worth notice.

IV. *Of the Peractor.*

THE Peractor is the same with part of that Theodolite, whose box is fixed to the plate; and the directions given for the Theodolite in page 27, will serve for this.

V. *Of the Plain Table.*

THE divisions on the limb of the Plain Table; with its box and needle, being like those of the Theodolite, or Modern Circumferentor; if the 360 degrees on the limb be upwards, and the box and needle screwed to the side of the table; it performs, in all respects, the use of the Theodolite, whose box is fixed to the plate. For lay the edge of the index on the division numbered 360, and to that numbered 180; and turn the whole instrument about, till through the sights you see the next station (the 360 being towards you, as shewn with the Theodolite) and there screw it fast; then turn the index about upon the center, till you see the last station, and so will the end of the index next you cut the degrees of the angle, and the south end of the needle will give the direction or bearing,

But if the box be screwed to the index, it in like manner becomes a Theodolite, with a box fixed to the index.

If the box and needle be screwed to the staff, it is a Circumferentor.

If the box be screwed to the table, and that side of the frame be upwards, which is divided into four nineties, it is the Perambulator.

If that side of the frame is upwards, which hath only the 180 degrees of the semicircle numbered on it, then it is a semicircle, either with the box to the plate or not, according as the box is fixed to the table or to the index.

And what hath been already said of these instruments may serve for directions, to use the plain table these several ways, and need not be again repeated here.

And

And hence it seems that the Plain Table might properly be called Panorganon, or the universal instrument, in respect of land surveying.

There are two small holes towards the middle of the board, which serve as centers to the divisions on the limb; the one for those when the table is used as a semicircle, the other for the degrees numbered as in a Theodolite; In these holes the protracting pin is to be set while the sloped edge of the index slides against it, and cuts the divisions on the frame. Now, if these holes were conical, and were the continuations of a conical hole in the index, so that the index could be fixed to them by a conical pin passing thro' its hole, and the central one, into which the pin screwed, the fiducial or sloped edge of the index being made to correspond with the center of the pin; also if the divisions on the frame be cut as accurately as on the limb of a Theodolite; and the wood would neither shrink nor swell any more than brass; and a telescope mounted on the sights; and the back side of the index brought also to a fiducial edge; then the Plain Table would be a very complete instrument.

It remains to shew, how to take angles when we use the Plain Table covered with a sheet of paper; but this hath been sufficiently handled by Mr. Leybourn, and almost all the common writers on Surveying; therefore I shall content myself with laying down a method to correct an error committed before it is communicated to the following parts of the work. Though I do not any ways doubt but the reader may, by what follows, learn the use of this plain instrument.

Suppose you were to draw the plan of the field ALMNQR: (Fig. 20.) Draw on the table a line to represent AL in the field, and by the scale lay down on the plan the length AL was found to be in the field, when you measured it with a chain.

Then

Then planting the table at L, lay the index on AL; and turn the whole instrument about till you see a mark set at A, then screw it fast, and turn the index about on L as a centre, till through the sights you see M, draw LM, and by the scale, give it on the table the same length you found it to have in the field, by measuring with the chain.

Now in order to examine the length of LM, and also its position in respect of AL; plant the instrument at M, lay the index on LM, and by turning the instrument, direct the sights to L, and there screw it fast; then direct the index turned about on M, towards A in the field, and if the edge does not cut the point A in the table, the line LM is false, either in position or length, and therefore must be examined and corrected before you proceed.

The line LM being truly laid down, plant the instrument at M, lay the index on LM, and direct the sights to L, by turning round the table, and screw the instrument fast: now turn the index about on M, till through the sights you see the hair cut N, by the edge of the index draw a strait line, and by your scale, from M lay the length NM equal to what you measured it in the field.

But to prove whether the line NM is truly laid down both in position and length; having planted the instrument at N, and directed the index laid on NM to M, and there screwed the instrument fast; from N direct the index to either of the marks L or A in the field; and if the index then does not accordingly cut L or A on the table, the line MN is false, and must be corrected before you proceed.

And in like manner through the whole survey, you may proceed to lay down every line, and examine it before you leave it, (provided that you leave all your marks standing at the stations,) by laying the index on the last line, and turning the instrument about till thro' the sights you see the

D

hair

hair cut the last mark ; and then screwing the instrument fast ; if you turn the index about on the point representing the station where the instrument stands, till you see any one of the marks passed by, except the last of all ; and if the edge of the index does not cut on the table, the representative of that point, the last line is not truly laid down.

But when from any station, suppose *N*, you cannot see any other mark but *M*, set up some mark *a*, from whence you may see some of the preceding marks, suppose *L*, as well as *M* and *N* ; and from this point *a* examine the truth of the position of the line *MN*.

Or thus ; you may set up a mark *a*, any where in the field, from whence all, or several of the angles may be seen ; then the instrument being at *A*, and the index on *AL*, screw the instrument fast ; and turn the index on *A*, till you see *a*, and draw *Aa*.

The instrument being at *L*, the index on *LA*, and the index directed to *A* ; let the instrument be screwed fast ; turn the index about on *L*, till thro' the sights you see *a*, draw by the edge of the index *La* ; and so will the point *a* be determined.

Then the instrument being at *M*, the index on *LM*, the sights directed to *L*, and the instrument screwed fast ; turn the index about on *M*, till thro' the sights you see the mark *a* in the field : then if the edge of the index does not cut *a* in the table, the line *LM* is false either in position or length.

In like manner the table being at *N*, the index on *NM*, the sights directed to *M*, and the instrument screwed fast ; turn the index about on *N*, and direct the sights to the mark *a* ; and if the edge of the index doth not cut *a*, on the table, then *MN* is false either in position or length.

Lastly, instead of a mark set up as *a*, you may use any remarkable tree, steeple, &c. not at too
great

great a distance from you, whether it be in the land you are then surveying, or not.

And when the mark you have last used is at too great a distance from you, or lies almost in the same strait line with that which you are about to lay down; then use some other mark in its stead.

VI. *Of working with the* CHAIN.

FIRST, provide a staff just 6 feet 7 inches and two tenths long, which divide into 10 equal parts; and so will the whole be the length of 10 links, and each part the length of one, and 10 times the length of this staff, the length of the whole chain.

With this staff examine the length of the chain, and also of every 10 links; stretching it on level ground, to such a degree as you design to stretch it, in the field work.

Before you measure with it, provide 10 arrows or small sticks, each about two feet long, and of such thickness, that a man may conveniently grasp 10 of them in one hand; also two strait staves about 5 feet long each: the arrows may be made of Ground Ash, a tough wood and not apt to break; let them be shod with sharp-pointed iron ferrils at one end, and have pieces of red rag tied at the other end, whereby they will be very readily distinguished and discovered when set down in long grass or corn.

When you are about to measure with the chain, let him that leads it take the 10 arrows and one of the staves; and he that follows it the other staff.

Then the follower standing at the station, let him by motions with his hand to the right or to the left, as they have before settled it, direct the leader to place his 5 feet staff at the chain's end in the same right line with the stations; and then let the leader

take up the staff, and in its place sticking down one of the arrows, go on.

Now the follower being come to the arrow, takes it up, sets his staff in the hole, and directs the leader to place his staff as before.

And then let the leader, standing at his staff, look back towards the last station, and he will see the staves and the station in one right line, if they have directed right. But if they are not in one right line, the leader must direct the follower to place his staff at the chain's end, in the same right line with the station, and the leader's staff.

And so, let each direct the other, till the two staves and the two stations are in one right line; and then must the leader put down an arrow in the place of his staff, and go on: and the follower take up his staff and the arrow where he last stood, and go after him.

And let them thus proceed till they have measured to the station, or till the leader is nearer the station than one chain's length; and then will the number of the whole chains measured, be expressed by the number of the arrows pricked down by the leader, and taken up by the follower, which suppose 8.

Now let the leader go on to the station, and there hold the end of the chain, and let the follower stretch the chain as usual, and then see how many links are contained between the last arrow and the station; which may be readily counted by help of different bits of brass, or curtain rings, or other marks fixed at the end of every tenth link, which links suppose to be 47.

Then enter in your field-book the chains and links without any distinction between them, and they will be 847; which imply either 847 links, or 8 chains 47 links.

But here we are to observe that the links must always possess two places; as 8 chains and 4 links must

must be written 804; that is 8 chains and 4 links, 804 links; and 8 chains without any links, must be written 800, implying 8 chains, or 800 links.

It is necessary that the surveyor should enquire of his assistants at the end of every measured length, how many arrows each hath; and if the sum of the arrows are not ten, it is evident they have dropt or left behind those that are wanting; and consequently the last length measured is doubtful, and must be re-measured before you proceed.

When you are come to the station, if it be convenient to continue the length, let the follower stand at the last arrow, and let the leader go on with the chain, and so place his staff, that it and the two stations are in one right line; then in the place of the staff put down an arrow, and go on; always directing himself to place his staff, and consequently his arrow, by the two stations.

When you have continued your length, till you have nearly lost sight of the farthest station, set up another station-staff in the place of the last arrow, and continue the length by the two nearest stations.

But withal take this caution, that it is not safe to continue lengths very long, when the stations are near one another.

When your length is very great, having measured ten chains, let the leader go on and set his staff down at the eleventh; now let the follower put his staff in the place of the leader's, and give the leader nine arrows, and then go on. But observe to enter in the field-book these ten chains, and never trust to your memory. And if the length consists of ten chains more, work as before, and enter 20 chains, and so on.

For a shift, the surveyor may perform many works with the chain; but this at best is both laborious and tedious, the only instruments for surveying all manner of lands both great and small in all cases,

being the Theodolites before-mentioned; yet lest there should sometimes be an absolute necessity for taking the position of a line by the chain when other instruments are wanting, we have here added the method of taking an angle therewith.

In order to do this, provide three round sticks, very strait, and about four or five feet long. And if you were to take any angle as DBC (fig. 21.) first place one stick upright in B, and there hold one end of the chain, and let your assistant carry the other end and another stick towards C, and direct him to move sideways, till the stick held upright at E, be exactly in the right line BC, at the chain's end, where let him leave it.

Then let him take the end of the chain and move towards D, and, as before, direct him to plant the third stick at the chain's end upright in the line BD at F.

Then measure the distance EF in links and decimal parts of a link, if less than one chain, and enter them in the field-book: so if the distance EF were 94 links and 7 tenths of a link, they might be enter'd thus, 08 947^{Parts}, denoting 0 sextants, 947 parts; the sextant standing for the chord of sixty degrees.

In this work great care ought to be taken, that the sticks be as strait as a workman can shoot them with a long plane; and that they are planted either exactly perpendicular, or at least so that the sticks planted at B and E, and the mark C may be exactly in the same plane, and also the sticks B and F, and the mark D in another plane.

But because it is very difficult to erect a stick exactly perpendicular, it will be easier to perform the latter thus; plant the stick as nearly perpendicular as you can; then move yourself backwards towards G, the farther the better, till your eye, the stick at B, and the mark at C, are all in one strait line, there stand and direct your assistant to plant his stick,

so that the stick at B exactly cover it from the top to the bottom.

But if it so happen, that you cannot move backwards at all towards G; then having planted the stick at B, as upright as you can, let your second assistant move forwards towards C, and let him there direct your first assistant to plant the stick at E, so that it exactly cover the stick at B, while you direct him to place it in a right line with the stick B and the mark at C; and the like caution must be used in planting the stick F. Nevertheless it will often happen so that the mark at D may be a little shifted, and in this case, time and trouble may be a little lessened; for having planted the stick at F nearly in a true position, move forwards towards D, and direct your assistant to incline the stick at F, so that it exactly cover the stick at B, then returning to B, direct your assistant at D to place the mark in a right line with the sticks B and F.

But, secondly, if the angle DBC is so great that the line EF be longer than the chain (as in fig. 22.) lay out a sextant; thus while the chain was laid from B to E, set down an arrow at H 50 links; then let your assistants hold the chain's end at H and B, while you, with the middle in your hand, move towards I and lay both halves strait; set down an arrow at I, which constitutes the equilateral triangle HBI; and thereby gives the angle HBI a sextant. Now the chain's end still held at B, stretch it through the point I to K, where also set down an arrow; then measure KF in links and decimal parts of links, which suppose to be 76 links and 4 tenths; and then shall be entered in the field-book 1^s 764, implying one sextant and 764 parts.

In like manner, if the angle were more than two sextants (as in fig. 23.) then having laid off the sextant HBI, let your assistants hold the ends of the chain at B and I, while you with the middle of the

chain in your hand set down an arrow at L, constituting the sextant IBL; and then as before, the chain being still held at B, lay it through L, and at the other end K, set down an arrow; then measure FK, which suppose to be 43 links and 5 tenths, and enter in the field-book $2^s 435$, that is, 2 sextants and 435 parts.

If you would continue a strait line, signify it by entering in the book $3^s 000$; that is, 3 sextants.

If an angle be external, and so contain more than three sextants (as in fig. 24); let one assistant hold one end of the chain at B, and let the other assistant stand with the other end of the chain at E, and there hold a stick, so that E, B and C, are in the same plane as before shewn; and let him also plant a stick at F, so that the sticks B and F, and the mark D be also in the same plane. Then measure the angle EBF as before, and to it add three sextants, and so will the sum be the measure of the external angle CBD. So if the angle GBD be $0^s 947$, then will the external angle CBD be $3^s 947$. But if the angle GBD be $1^s 764$, then the external angle CBD will be $4^s 764$. And if the angle GBD be $2^s 435$, then the external angle CBD will be $5^s 435$.

Now to plot any of these angles thus taken (suppose that in fig. 21); chuse some line divided into 1000 equal parts, and with this line as a radius from the center B describe an arch ER, and lay thereon from E to F 947 equal parts and draw BD.

And if you would plot the angle (taken in fig. 22); from B with the length of the divided line, describe an arch EF, and lay thereon the length of the divided line from E to K, and afterwards 764 parts from K to F, draw the line BFD, and you will construct the angle required.

Again,

Again, if you would plot the angle of fig. 23; then as before, with the length of the divided line, from B describe the arch EF, and thereon lay EP, PK, each equal to the radius; and afterwards lay 435 equal parts from K to F, draw BF; and you have the angle required.

And if you would protract an angle greater than three sextants (as the external angle CBD in fig. 24); first continue the line CB, then from the angle subtract three sextants, and make the angle GBD equal to the remainder.

Angles about gardens or buildings may be taken with rods of five and ten feet, and laid down in all respects as with the chain, but are no ways fitting for large plans.

If the Surveyor has only a chain, and having drawn his plan, would draw thereon a meridian line; he may do it thus; exactly at twelve o'clock, mark the shadow of some upright object, as the corner of a house, or some streight tree, or your staff set upright; then plot this line on your plan, and it is a meridian line.

Or thus; in a night when the Pole-star is to be seen, place yourself so, that your eye, the Pole-star, and some upright object, as the corner of a house, or the side of a streight tree, be in one streight line; then plot the line from your feet to the upright object, and it will be a meridian line.

Indeed the Pole-star moves round the real pole; but at so small a distance from it, that in this case the variation may be rejected.

How

However, you may observe that the Pole-star is

full north about the 20th day of	{	March and September at 12,
		April and October at 2,
		May and November at 4,
		June and December at 6,
		July and January at 8,
		August and February at 10

o'clock either morning or evening; always increasing nearly two hours for every month.

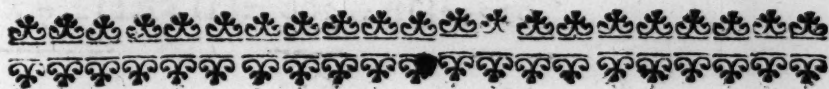
Therefore if the observation is made about these times, the variation will be very inconsiderable.

Also observe, that five, six, or seven hours before or after these times, if the pointers are to the eastward of the pole, then the variation of the star is about three degrees and a half westward; and is then the greatest.

But if to the westward of the pole, the variation is about three 1-half eastward, and then at the greatest.

NOTE, The pointers are the two hinder wheels of the constellation, call'd Charles's Wain, which are observed to be always in a direct line with the Pole-star.





S E C T. IV.

*To cast up the CONTENTS of LAND, with
the Method of reducing Irregular Curves to
Streight Lines.*

THE contents of any field may be readily cast up thus: Take each base and perpendicular of every triangle, and each diagonal of every Trapezium, in links, esteeming every chain 100; in every Trapezium multiply the sum of the perpendiculars by the diagonal; and in every single triangle, the base by the perpendicular; then add the several products together: Put a point between the fourth and fifth places, and another between the fifth and sixth, reckoning from the right hand; then halve the figures to the left hand of the points, and so will this half be acres: if an unit remain, that unit is an half acre or two roods; and if the figure between the points be five or more, take five from it, and account it another rood. Then multiply the remaining figure 0 between the points, by 8, and to the product add the tens to be carried from the fourth figure, and you have the perches. If any person is so curious, as to esteem the decimal parts of the perches, they will be the product made by multiplying the figures to the right hand of the point by 8. So in figure 25, the operation will be thus.

$$\begin{array}{r}
 313=AC; 214=KL; FG=418 \\
 612=DE; 396=HI; AH=900 \\
 \hline
 925 \qquad 610 \qquad 376200 \\
 725=BF \quad 500=FM \\
 \hline
 4625 \quad 305000 \\
 1850 \\
 6475 \\
 \hline
 670625
 \end{array}$$

$$\begin{array}{r}
 670625 \\
 305000 \\
 376200 \\
 \hline
 13|5|1825 \\
 \text{A. R. P.} \\
 \text{Answer, } 6 : 3 : 1
 \end{array}$$

Here half of 13 gives 6 the acres, and one remaining is 2 roods; then the 5 between the points gives another rood; and so the whole is 6 acres and three roods; and because there is but one ten to be carried from the fourth place, and that after the 5 is taken out of the fifth, there remains nothing, there is but one perch.

In like manner, if the whole sum of all the

		A.	R.	P.
Products be	$ \left\{ \begin{array}{l} 17 4 5364 \\ 11 9 2765 \\ 10 5 4321 \\ 8 4 3764 \end{array} \right\} $	the con-	tent is	8 . 2 . 36
				5 . 3 . 34
				5 . 1 . 03
				4 . 0 . 35

So if the sum of the products be 41|7 6354, the content is 20 . 3 . 21|0832. But this method must be only used when the figure is reduced to triangles and trapeziums.

It may not be improper to add in this place, the manner of casting up such fields as consist of many small

small breaks in the hedges ; without reducing them to a multitude of triangles ; thus,

Let fig. 26. be such a field ; produce NM, one of the longest sides ; then lay the edge of a streight ruler from M, one of the angles at the end of NM, to G the next angle but one ; holding the ruler thus fast, take with a pair of compasses the distance from L to the edge of the ruler, and with this distance let one point of the compasses move gently close to the ruler, while the other point traces out a line parallel to it, and crosses NM in Q. Now draw GQ, and it will reduce that side of the figure, which was bounded by the two lines ML LG, to another bounded by GQ, one single line only.

In like manner QG being produced, and a ruler laid from G to E, carry the distance of F from the ruler parallel to it, till you cross QG in K. Then lay a ruler from K to the next point D, and carry the distance of E from the ruler parallel to it, till you cross QG in H. Now lay a ruler from H to the next point C, and carry the distance of D, the last point from it, parallel, till you cross QG in I. Lastly, draw IC, and the side GC, which consisted of the four lines GF, FE, ED, DC, will be reduced to the side IC, consisting of one line only. And in like manner we might proceed if the lines were never so many.

And thus laying a ruler from C to P, draw PO ; and in like manner AQ. So will the ten-sided figure be reduced to a four-sided one, and so may be cast up by one multiplication only. The practice of this will be rendered vastly easy by help of a parallel ruler.

Provide a plate of thin brass in form of an arch of a circle ; near whose ends let there be drilled small holes, through which string it with a very fine hair or wire. Being thus provided ; when a hedge at GC bends in and out in several places, and those
bends

bends contain very small spaces, lay the hair over it lengthwise, so that the quantities thereby cut off from the figure may be equal to those added to it; and with your protracting pin, near the ends of the hair, make two marks, thro' which draw a streight line; and so will this irregular side be reduced to a regular one. And here we may observe, that in very small bends, we judge better by the eye than we can by the compasses of the equality of the parts taken in and left out.

But, if hedges consist of large curvatures, chuse out such points, and so many of them, that right lines drawn from point to point, may vary the quantity by such parts only as may be rejected. And herein your hair will be a ready assistance.



SECT. V.

Of the Laying out or Dividing of LAND.

WHEN any number of acres, roods, and perches, are to be laid out, or measured off from another field, it is convenient to reduce them to square links, which may be done thus:

If the roods are $\begin{Bmatrix} 1 \\ 2 \\ 3 \end{Bmatrix}$ add $\begin{Bmatrix} 40 \\ 80 \\ 120 \end{Bmatrix}$ to the perches,

and to the sum annex 4 cyphers. Divide this last by 16, or by 4 and 4, and write the quotient figures, if they consist of 5 places, after the acres.

But when the number of quotient figures are but $\begin{Bmatrix} 4 \\ 3 \end{Bmatrix}$ write $\begin{Bmatrix} \text{one cypher} \\ \text{two cyphers} \end{Bmatrix}$ after the acres, and then the quotient figures; and so you will have the square links required.

Ex-

[47]

A. R. P.

Ex. I. Reduce 7 2 24 to square links.

to 24 perches,
Add 80, because 2 roods

16) 1040000 (65000
80000

Answer 765000.

A. R. P.

Ex. II. Reduce 7 0 11 to square links.

to 11 perches
Add 0 because 0 roods;

4) 110000
4) 27500

Quotient 6875 has four places.

Answer 706875.

A. R. P.

Ex. III. Reduce 7 0 01 to square links.

to 01 perches.
Add 0 because 0 roods,

16) 10000 (625 three places
40
80

Answer 700625.

A. R. P.

Ex. IV. Reduce 13 3 37 to square links.

to 37 perches,
Add 120 because 3 roods,

4) 1570000
4) 392500

Quotient 98125 has 5 places.

Answer 1398125 square links.

In

In the laying out of lands, there are three cases, or Problems, which arise in practice.

For either the partition line is required to be parallel to some other line assigned, or is to pass through some point assigned in the fence, or to pass through some point assigned within the land.

In the solution of each of these cases, I chuse an arithmetical approximation rather than a geometrical construction ; for reasons sufficiently known to those who have practised.

Note, When a quantity of land is to be laid out, or taken off from a field, it is necessary to have an exact plan of the place, or field ; and this is supposed in the following problems.



P R O B.

P R O B. I.

From the Field HGEKF, Fig. 27.

Let it be required to cut off towards AB, 8 Acres, 3 Roods, 18 Perches, by a line drawn parallel to AB.

FIRST draw parallel to AB a line CD by guess, near the place where it is imagined the partition line should be; and then cast up the content of the figure CDHG, which suppose to be 772575 square links, which is less than 8^{A.} 3^{R.} 18^{P.}; or 886250 square links, by 113675 square links; which shews, that the partition line should be more towards K.

Now divide the excess 113675, by 965, the length of CD in links, and at the distance of 118 links, the quotient, draw EF parallel to CD, and it will be sufficiently near the partition line required.

But if by curiosity you are led to correct the variation, you may conceive CD to be a line given in position, and 113675 square links, to be the quantity to be cut off, and EF the line drawn by guess.

But if the line CD had cut off the quantity CDHG greater than that required, then the partition line had been more towards GH, whose distance from CD would be found as before, by dividing the difference by the length of CD.

P R O B. II.

From the Field LMPQRSTW, Fig. 28.

To cut off 5^{A.} 0^{R.} 35^{P.} toward the corner L, by a line drawn from the point V.

REDUCE the given quantity 5^{A.} 0^{R.} 35^{P.} to square links, and they will be 521875.

Then draw LV, forming the triangle VLW, which being cast up, amounts to 30800 square links, which is too little.

To the next angle draw VM, forming the triangle VLM, which being cast up will be found to amount to 297632 square links, which added to the triangle VLW, you have 328432 square links, the content of the Trapezium VWLM, which is still too little.

To the next angle draw VP, forming another triangle, whose content 403850 square links added to 328432, the content of the preceding figure, gives 732282 square links; which is more than the required quantity, by 210407 square links; therefore the partition line must pass between P and M.

Divide the excess by 497, half the length of VO the perpendicular in links, and lay 423 the quotient from P to N, and so shall VN be the true line of partition.

P R O B.

P R O B. III.

In the Field BCFGH, Fig. 29,

*To lay out 7^A. 3^R. 13^P. towards the corner B,
by drawing one or two lines through a point
A within the field.*

TO perform this with one line : Consider thro' which two sides of the field the partition line will pass. Reduce the figure to a Trapezium, still retaining those sides, as shewn in page 45. Which divide by a line through the assigned point A.

But, because this method is tedious, and depends on the concurrence of many lines; and though we should use numbers, we should little mend the matter, and indeed is often impossible to be performed by one single line, it may not be amiss to shew how to do it by two lines.

From A to any two angles H and B, draw the lines AH, AB, forming the triangle AHB, this being cast up, amounts to 338000 square links, which is less than the quantity required.

To the next angle C, draw AC, forming the triangle ABC, which being cast up, amounts to 322500 square links; which added to the triangle AHB, gives 660500 square links; which are still less than the quantity required.

To the next angle F draw AF, forming the triangle ACF, whose content 280800 square links, added to the preceding triangles AHB, ABC, gives 941300; which exceeds the quantity required by 158175 square links; now divide this excess 158175 by 292, half the length of the perpendicular EA, lay the quotient 541 from F to D, and draw AD; and so will the lines AH, AD, be the partition lines required; and the figure AHBCD will contain the given quantity which was to be laid out.



S E C T. VI.

The use of the Theodolite exemplified in Surveying several parcels of land lying together, with the form of a Field-Book.

AFTER a general description of instruments and their uses, some practical examples are necessary to illustrate and explain the particular varieties which often occur.

The following example is delivered in the same method, which at this time is commonly practised.

The instrument used in this survey is a Theodolite numbered on the limb from the left to the right, and in the box (which is fixed to the index) the same way, the eye being supposed in the center.

The Chain, the Off-set-Staff, the Arrows, &c. are as described in the third Section.

In one end of the Off-set-Staff, it will be convenient to screw in a piece of iron, having at the end a kind of fork, whose legs shall be just long enough to embrace the hand-ring of the chain, which being put in the fork, the end of the chain may be thrust through a hedge by the means of the Off-set-Staff, to the leader of the chain on the other side of the hedge.

The field-book may be divided into three columns: The middle one contains the several lengths taken by

by the chain; and the outside columns contain the several off-sets, and the description of the most remarkable objects, which are to be met with in the survey.

By the mark $\odot$ is denoted a station; by $\sphericalangle$ an inside angle; and by $>$ an outside angle; by (B) is denoted a bearing; by *int.* the cutting a hedge by the chain; by *ag.* some remarkable object on the farther side of the hedge. These symbols are used instead of words, because they constantly fall in the way; but other objects, which are more rarely met with, I express by words.

Being thus provided, in the first page of the field-book, near the top, enter the title of your survey: Then having fixed the instrument in some convenient place, as A to begin at, I enter in the middle column the mark $\odot$ 1. denoting the first station.

Here observe, that I always chuse to work in a lane, as often as opportunity presents.

The instrument being planted at A, I send a station-staff forwards in the lane, as far as I can see distinctly, the farther the better, suppose to (B 3.) and when I work in the land, I send a station-staff to the next eminent bend in the hedge, or even to the farther end of it, if the line from the instrument to the staff be not at too great a distance from the hedge, so as to cause off-sets greater than a chain, or a chain and a half, or thereabouts. For off-sets taken too great, produce some uncertainties.

Then I observe the bearing of the line AB, thus; the flower-de-luce in the box being towards me, I direct the sights to B 3, and then find the needle cut 327° , which I enter in the middle column under $\odot$ 1, thus, B 327° .

NOTE, By the instrument used in this example, the bearing is accounted from the north, westward quite round to 360° .

The observation being made of the line's position, which I am about to measure, the next thing is to lay

the chain from this station A in a right line towards the next station B 3 ; which being done, I let it lie, till I have entered the occurrences in this chain's length, *viz.* I measure the distances of the chain from the brow of each ditch, which I enter in the outside columns, that on the right hand of the chain in the right hand column, that on the left in the left hand column ; and also the names of the persons, who own these lands abutting ; or if these lands are some of those which I am about to survey, I enter the names of them ; and, in all cases, express to which land the hedge belongs.

These precepts will not be repeated, tho' I shall ever make use of them ; but if any other are used, they will be laid down the first time they occur in this example, but not afterwards.

Now I enter 0 in the middle column, and 20 in the right hand one, and 20 in the left ; denoting, that at no distance, or at the instrument, the ditch on the right hand is 20 links from the chain, and that on the left also 20. In the right hand column, I write William Wary's land, hedge to Wary ; and in the left, Lord Title's land, hedge to Lord ; because the land and hedge on the right is Wary's, and that on the left my Lord's.

Being now come to *a*, I am right against the south hedge of Hazle Spring, and also of Woodfield, and there find the distance from the ditch on the right hand to be 25, and on the left to be 20, and that afterwards the hedge on the right hand belongs to Hazle Spring, and on the left to Woodfield. Therefore I enter in the middle column 65, and in the right hand column 25, *ag.* hedge to Hazle Spring, hedge to Spring ; and in the left 20, *ag.* hedge on Woodfield, hedge to field.

Here it may be observed, that these off-sets, or distances of the chain from the hedge, are measured with my ten-link staff, which I therefore call my Off-set.

Off-set-staff) perpendicular to the chain, and so far till I come to that brow of the ditch, which is farthest from the stem of the hedge: And that here by the brow of the ditch, I mean the determined distance of five links from the stem of the hedge. And in order to lay this staff perpendicular to the chain, it would be convenient to have two pieces at one end of it at right angles, like the squares used on a drawing-board; and these pieces, for convenience of carriage, may be made to fall into the staff, by springs like a clasp-knife.

Having entered these observations in the first length of the chain, I observe what place of the ground is exactly under the center of the instrument, by dropping a musquet-ball, or plumbing it with a string and weight; then I remove the instrument, and in that place fix, as upright as can be, a station-staff, and then proceed with the chain.

And because in the second and third lengths of the chain I meet with no sensible turns in the hedge, nor other material occurrences, I go on to lay it a fourth time, and there against 45 links I find a bend in each hedge; where on the right hand the brow of the ditch is 50 links distant from the chain, and on the left 40; therefore in the middle column I enter 345 (denoting 3 chains 45 links) and in the right hand column 50, and in the left 40.

And here it may be observed, that I take off-sets only at each end of such parts of a hedge, as run very nearly streight, omitting the intermediate parts; since when the extremes of a right line are given, that right line itself is also given: So here, though the distance of the hedges from the chain between *a* and *b* continually vary, yet I only take the off-sets at *a* and *b*, since these are sufficient. But when the hedge runs on with a continued but irregular curvature, I take off-sets at every chain or half chain's length, or perhaps oftner, as the thing requires. But

when the curvature is regular, I take its extremities by off-sets, and express its nature by a sketch, in the outside columns.

In going on from *b* towards *B*, when I am come to *c*, the chain touches the brow of the left-hand ditch, against 20; then I ask the hindmost man, or the follower of the chain, how many arrows he hath? he answers 5; then I enter in the middle column 520 (denoting 5 chains 20 links) and in the left hand column 00, denoting that the brow of the ditch is at no distance from the chain. The chain still lying, against 40 links, I find a bend in the right hand hedge, where the ditch is distant from the chain 50 links.

Now it may be observed, that I frequently ask the follower of the chain, and also the leader, how many arrows they have? especially when I am about the off-set or other occurrence, partly to know the number of the chains, and partly to prevent the loss of an arrow; for this always raises a doubt of the length, and must be removed before we proceed; and lest when a stick is dropped, another may be picked up in its room, I always give my arrows some marks of distinction.

If the sum of the arrows in both my assistants hands are less than ten, than the last length must either be re-measured, since it is doubtful, or else the surveyor must step it, and thereby discover which of them dropt it: And this, with a little practice, he will easily do by counting his steps, and using himself to stride about the same distance each step; and by loosing a button of his coat when he hath gone as many steps as (by experience he knows) carry him the length of a chain. And hence he may know exactly the number of the chains, though he cannot perhaps find exactly the odd measure. But the number of chains is sufficient, because the error by dropping arrows always falls in whole chains.

In

In like manner, at the length of just 800, because the chain touches the right hand ditch, and is distant from the bend in the left hand 40 links, I enter in the middle column 800, in the right hand column 00, and in the left 40.

Then I continue on to my station-staff at B₃, which I find to be at the length of 825, where, because there is no bend in the hedge, nor other material occurrence, I enter 825 in the middle column, and under it I draw a line, denoting that this length, and all the occurrences therein, are observed and entered in the field-book.

Since I have endeavoured to be plain and easy in this first length; so shall I, in the following part of this example, be as concise as may be, unless where something arises not before spoken of; referring the reader rather to the field-book and explanations, than tiring him with repetitions.

Being come to B₃, I there so plant the instrument, by help of the plummet, that its center is directly over the hole which the station-staff stood in; and I send my station-staff forwards, as far as I can conveniently see it as to C.

Now with the beginning of the degrees towards me, I direct the fixed sights back to the staff at A, and screw the instrument fast; and then with the flower-de-luce towards me, I direct the index to the staff at C, and there find, that the end of the index next me, cuts $202^{\circ} 45'$, and the south end of the needle points at $304^{\circ} 15'$. Therefore I enter in the middle column of my field-book, $\odot 2$, and under it $\sphericalangle 202^{\circ} 45'$, and next under this B $304^{\circ} 15'$; denoting, that at the second station, the angle made, is $202^{\circ} 45'$, and the bearing of the second length is $304^{\circ} 15'$.

But before I proceed, I examine these numbers thus: To the bearing of the last station 327° , I add the constant number 180, and from the sum 507° ,
subtract

subtract the present bearing $304^{\circ} 15'$; and find the remainder $202^{\circ} 45'$, exactly equal to the angle.

Or else, to the angle $202^{\circ} 45'$, I add the present bearing $304^{\circ} 15'$; and from the sum 507° subtract the constant number 180, so shall the remainder 327° be the bearing of the last length exactly, as taken at the last station.

And this operation I place in the outside column against the same angle and bearing, to signify that the angle and bearing have been compared, and do agree.

But if these numbers thus compared, do not agree, the present angle and bearing must be examined and corrected; and if, after such examination, they do not agree, there is an error in the last bearing, which may be taken again; thus,

The instrument standing in the same place, I direct the index, the flower-de-luce being from me, to the last station-staff at A; and then will the south end of the needle point at the same degrees which it did when the instrument stood at A, and the index was directed to B³.

Having thus taken, entered, and examined the angle and bearing, I proceed with my chain, and find the lengths and occurrences to be as you see them in the field-book.

Then fixing the instrument at C, as before shewn, observing always to set the plate horizontal by the help of a spirit-level, or otherwise; I send a station-staff forward to D, and observe, enter, and prove the bearing and angle at C; and then stretching the chain towards D, I find at the length of 250, a gate on my right hand, and at 260, at the distance of 10 links, the corner of Hazle-Spring. Therefore in the middle column I enter 250, and right against it, in the right hand column, I write *Gate*; again, in the middle column, I enter 260, and right against it, in

in the right hand column, 10 *Corner*, and then proceed to the station-staff at D.

Having finish'd the length CD, and fixed the instrument at the fourth station D, I do not go up the lane towards E, but turn off towards L; in order to close in Hazle-Spring and Spring-Close; always observing this rule, *viz.* Never to make a tour greater than necessity requires, but always to close as often and soon as possible.

Therefore having sent a staff to L; I observe, enter and prove the angle and bearing at D.

Here it may be observed, that when I came to K in the first length, the hedge on the left hand belonged to Woodfield, and not to the lane; and therefore I entered in the left hand column, Hedge to Field; and since this note, the hedge on the left hand hath continued to belong to the same Woodfield; therefore I have not repeated that occurrence. But in going from D to L, at the length of 15 links, I am against the corner of Long Mead, and 10 links distant from it, and then the hedge belongs to Long-Mead. Therefore after $\odot 4. \sphericalangle 259^{\circ} 20'$, $B 261^{\circ} 10'$, I enter in the middle column 15, and on the left hand 10 *Corner*, then on Long Mead, then Hedge to Long Mead.

But because on the right hand we have still Hazle Spring, and the hedge is still to the Spring, and because these have been always on the right hand since I first entered them, I go on without any farther remark, till I meet with a different occurrence.

Being come to L, I observe, enter, and prove the bearing and angle, and then proceed to M. At M I observe and proceed in like manner to N. But at N, the seventh station, instead of going on in the line, I proceed to close in Hazle-Spring, and therefore send a station-staff to O in Spring Close.

Therefore at the seventh station N, in the lane, having observed, entered, and proved the angle

MNO,

MNO, and the bearing of the line NO, and directed the chain from N towards O; I find the chain cuts the brow of the ditch at 10 links distant from N; therefore in the middle column I enter 10 Int. denoting the chain's intersecting the hege, and then I write In Spring-Close, denoting that the land we are in is called Spring-Close; and in the right hand column, but the next line, I write Hazle-Spring, and under this, Hedge to Spring, denoting that the land on our right hand is Hazle-Spring, and that the hedge belongs to the same. Then I proceed to observe, measure, and enter those occurrences as they are found in the field-book, till I come to O.

At O, I observe, enter and prove, and proceed as usual towards Q; noting that at the length 720 the chain did cut the hedge in the very corner of the fence; and therefore enter in the middle column 720 Int. and in the right hand column 00 Corner, and then in the middle column I write, In William Wary's Land; and so proceed to Q.

Being come to Q, the ninth station, I send a station-staff towards A; and then observe, enter and prove my angle and bearing; and so proceed with the chain, entering all occurrences, as in the field-book; till coming to the length 830, I find myself right against the corner of Hazle-Spring, and 43 distant from it; which being entered as you see in the field-book, I write in the middle column * Close Haz'e-Spring, denoting that the extremity of this off-set coincides with the first off-set taken to Hazle-Spring.

Having thus completed Hazle-Spring, I return to N, my station in the lane, according to that general rule I always observe of working in a lane, and according to that rule of closing as often as possible.

Now turning back the leaves of my field-book, I find the station immediately before my coming
into

into Spring Close, was by number the seventh. Therefore, in my field-book, I enter $\odot$ 7.

But here it may be observed, that whensoever I design to return to the same station, before I leave it, I cut a turf from the hole where the staff stood, or leave some other mark, whereby I may exactly find it again readily; and in the field-book to the mark $\odot$, I prefix the letter R, or write the word Return: by which, and the other concomitant notes, I readily discover the number of the station.

But when the $\odot$ to be returned to, falls in a way where many carriages, &c. pass; or when it may be thought proper, as a cheque on the foregoing work, to direct a line from some convenient $\odot$ to a former $\odot$, several days after you departed from that former $\odot$; in such cases, it will be best to drive a plug, cut from a hedge-stake, and pare the ground away, or leave a few stones, about this plug; or make some mark in the hedge opposite to this plug, whereby it may be readily found again; observing to conceal these plugs or marks from the country-people, who in general, hating the practice of taking surveys of their grounds, will frequently remove the surveyor's marks, either to give him trouble, or divert themselves.

And for the convenience of the ready cutting and driving of these plugs, one of the assistants should have a small hatchet stuck in his girdle; besides, such an instrument is often wanted to cut away the small stuff in a hedge, in order to open a proper view to the station-staff.

Having now planted my instrument a second time at N, and sent a staff forward to R, I observe the angle MNR, made by the line NR, I am next about to measure, and the line MN, that which I measured immediately before I came to N the first time.

And

And this I always make a constant rule, *viz.* To observe the angle with that line which was measured immediately before I came to the station, where I took the angle the first time. So here I observe the angle made with MN, and not with any other as ON, and therefore in proving the angle MNR, I use the bearing of MN taken at M.

Now having taken, entered and proved the angle MNR, and the bearing of NR, I go on with the chain towards R, entering the several occurrences as you find them in the field-book.

Being come to R, the tenth station, tho' my design is to inclose Spring Close, yet because the last length, continued it's traile forwards, will take the fourth hedge of Long Mead; in the middle column I enter $\odot 10$, $\sphericalangle 180$, B. 274. 45. and then direct the leader of my chain to lay it right forwards by help of the stations R and N; and accordingly I enter the occurrences of that length, as you see in the field-book.

This finished, I return to R, and sending a station-staff to S, I enter again $\odot 10$, and the angle and bearing at R, and so proceed to S.

And then from S to T, and so from T the 12th station to P, inclosing Spring Close.

Spring Close being finished, I return to my fourth station at D; and send a station-staff forwards to E, and then under $\odot 4$, observe and enter the bearing of DE, and the angle CDE; and then by the bearing of CD, taken at the station C, immediately before I came to D, prove the angle CDE, and proceed with the chain, entering all occurrences as usual.

Being come to E, I send a station-staff to F, in order to close in Woodfield. Now, after I have observed and entered the angle and bearing at the thirteenth station E, when I come to prove them, I find by adding 180° to $353^\circ 15$, the bearing of the line
which

which brought me to this station; and when from the sum $533^{\circ} 15'$, I have subtracted 82° , the present bearing, I find the remainder to be $451^{\circ} 15'$, a number greater than the 360. Now as oft as this happens, I lessen this number by 360 degrees, and so will the remainder be, as in this example, $91^{\circ} 15'$, the present angle exactly.

Then entering the occurrences, I proceed to F, and in like manner from F to G, from G to H, from H to I, and then from I, the seventeenth station, to K, thereby inclosing Woodfield.

This done, I return to E, and there because I can continue my length DE, right forwards conveniently, I enter $\odot 13$, $\sphericalangle 180^{\circ}00'$, B. 353. 15. and then go on to V.

And then entering angles, bearings, and other occurrences, I proceed from V to W, and from W to X, the 20th station.

Being come to X, and having entered $> 234^{\circ} 20'$, and B $307^{\circ} 40'$, then after I have added $180^{\circ} 00'$ to the last bearing $2^{\circ} 00'$, I find the sum $182^{\circ} 00'$ is less than $307^{\circ} 40'$ the present bearing: in such cases I always add 360 to the sum 182, and then from the result, taking the present bearing $307^{\circ} 40'$, the remainder will be, as in this example, $234^{\circ} 20'$, the present angle.

Then I proceed to Y, and from Y to Z.

Being come to Z, the 22d station, in order to enclose Long Mead, I go off to α , from α to β , from β to γ ; where, because the several bends of the river cannot so commodiously be taken without it, from γ I go off to δ ; and then from γ to ϵ , from ϵ to ζ , from ζ to η , and from η the 28th station, to θ ; thereby inclosing Long Mead. And then return to Z. But observe that at station 23 where the river falls in, the breadth should be taken, and wrote in the field-book; and in coasting the river, its breadth should be taken in several places, and marked

marked in the field-book ; also at station 28 where the river ceases to be the fence, it must be noted, together with its breadth ; the course of the river, or the way it runs must be likewise entered in the book.

Being come to Z, I find it convenient to continue my length strait forwards ; and therefore under $\odot$ 22, I write $\sphericalangle$ 180, and so go on to η , from π to λ , from λ to τ ; and then in order to inclose Butts Close, I go off from τ , the 31st station to ρ , and ρ to σ .

Then returning to τ , I go on to A^2 the 33d station, and then, in order to close the Home Close, I go off to B^2 , and so then to C^2 , and D^2 .

Returning then to A^2 , I go on to E^2 , from E^2 to F^2 , from F^2 to G^2 , and G^2 to H^2 , the 39th station.

Being come to H^2 , in order to close in Mottle Mead, I go off to I^2 , from I^2 to K^2 , from K^2 to L^2 , the 42 position, and from L^2 to M^2 , and so is Mottle Mead finished.

Then in order to inclose Hazle Wood, I go from L^2 to N^2 , from N^2 to the angle at F, and so is Hazle Wood finished.

Then I return to H^2 the 39th station, and thence go to O^2 , and from O^2 to P^2 , the 45th station.

And now, in order to close in Hazle Field, I go from P^2 to Q^2 , and from Q^2 to T^2 .

Which being done, I go from P^2 to R^2 , and from R^2 to S^2 ; and so the whole is finished as you find it in the field-book ; and as far as relates to the field work.

It remains to shew, how this work may be plotted without any regard to the memory ; nay, though it were survey'd by one person how it may be plotted by another who never saw the land ; provided that the person who survey'd it, hath strictly observed the rules here laid down. And I do affirm, that any

any method of keeping a field-book, which lays a burthen on the memory, or by which, a person remote from the land, cannot plot it, is imperfect, and ought not to be practised.

But it may not be improper, to advertise the reader, that there is one thing absolutely necessary to be taken notice of, in observing with any of the foregoing instruments, *viz.* that the plate must lie always parallel, or very near parallel to the plan of the horizon.

Likewise, he ought to allow for the difference between ascending and descending lengths, when compared with the horizontal length.

For it is evident, that the length measured up an ascent, or down a descent, will be always greater than the horizontal lengths, which only are the measures that ought to be entered, either for casting or for drawing the plans of any parcel of land whatsoever; since these ascending measures, if laid down, would crowd the adjacent ones out of their places.

And since these things are required very frequently, many times in going upon one ascent, and consequently ought to be performed in the field, in order to make a proper entry in the book, I would have the practitioner be provided with such a Theodolite, as will perform without compasses, rulers, sectors, tables, &c. these useful practices, or without any further observations than what is required to take the angle only. Such Theodolites may be made, not only to perform these, but also to shew by inspection, the height of any standing stick of timber, without any calculation, tho' the stick stood on level, rising, or falling ground: Or the length of any arm out of reach; or height of any steeple or hill: Or by it a level, proper for the conducting of water; very useful for all surveyors in general.

Tho' I do design to give a specimen of this improved instrument, hereafter, in all its conveniencies

nencies, I could not pass it by in this place, lest the reader should over-look it.

In this place it will be proper to observe some particulars, which experienced surveyors have found necessary.

In taking the Theodolite thro' a hedge, it sometimes happens, that a thorn or sprig, catching the horse-hairs in the sights, breaks them; therefore the surveyor should have spare horse-hairs ready, and a piece of dry stick to cut a sharp point, to fix fresh horse-hairs to the sights.

In running the chain along a field where are many furze-bushes, thorns, or other short stuff, (or by other accidents) the links will be frequently bent, and the rings opened, whereby the chain parts; in such case, a small hand-vise, and a pair of nippers should be ready, that the chain may be put together again, the rings closed, and the links straitened: And lest some of the links should be broke, or the rings lost, there should be spare links and rings at hand. One of the chain-men may easily carry these articles in his pockets: And it will be proper that one of them should every evening, or the morning before he goes into the field, examine the chain from end to end, and rectify what may be found amiss.

In cloudy dark weather, or towards the evening, the station-staves cannot be easily seen, unless at short distances; and as it is much better on all accounts, to have them at long distances when that can be had, and is a loss of time to set intermediate staves; therefore if pieces of tin, or other white marks were ready to fix to the top of the staves, the surveyor would find his account by such precautions.

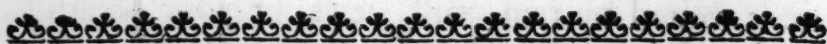
It

It often happens, that the glass which covers the box is wetted by rain, mist, dews, or your breath; now in wiping this off to see the needle, the glass by being rubbed becomes electrified, and thereby attracting the needle, prevents its free motion: It is necessary the surveyor should be apprized of this, and that by touching the glass with his finger wetted, over the place to which the point of the needle adheres, it will be released from the electrical attraction, and move towards the position into which its magnetical virtue directs it.

An industrious surveyor will not leave the field for a small mizzling rain; and altho' he cannot then write in his book with ink, yet his observations may be entered with a black lead pencil, and these wrote over with ink when he returns to his abode.

There are several things that occur in a survey, which cannot with convenience be entered in the field-book by the foregoing directions, such as, places where are many bushes, pits, or other obstructions where the instrument and chain cannot be readily directed; also the site of houses, barns, yards, ponds, &c. Such things shou'd be entered in the field-book by a sketch or drawing in the opposite page, and such lines measured with the chain or off-set-staff, as are necessary to furnish the means of making a true plan thereof.





Observations and Dimensions of Lands lying in
the Parish of — in the County of —
Part of the Estate of —

February the 2d, 1725

Beginning at the Lane leading from Hardly to Roughton.

		⊙ 1	
		o ,	
		B 327. 00	
On Lord Title	20	o	20 On Will. Wary
Hedge to Lord			Hedge to Wary
ag. Hedge	20	65	25 ag. Hedge
On Woodfield			On Hazle Spring
Hedge to Field			Hedge to Spring
	40	345	50
	00	520	
		540	50
	40	800	00
		825	

		⊙ 2	
o ,			
327. 00			
180. 60			
507. 00			
304. 15			
202. 45			
	15	240	
		250	10

[69]

0	1	0	3	
304.	15			
180				
484.	15	0	1	
340.	30	< 143.	45	
		B 340.	30	
		250		Gate
143.	45	260		10 Corner
		270		
340.	30	R 0	4	
180				
520.	30	> 259.	20	
261.	10	B 261.	10	
259.	20			
Corner	10	15		
On Long Mead				
Hedge to L. Mead				
	15	220		
261.	10	0	5	
180				
441.	10	< 156.	50	
284.	20	B 284.	20	
156.	50			
		10	165	10
284.	20	0	6	
180				
464.	20	> 206.	50	
257.	30	B 257.	30	
206.	50			
		10	230	10 against Hedge
				On Spring Close
				Hedge to Spr. Close
			240	
		F	3	

$\begin{array}{r} 0 \\ 257.30 \\ 180 \\ \hline 437.30 \\ 173 \\ \hline 264.30 \end{array}$

[70]

R 0 7

$\begin{array}{r} 0 \\ >264.30 \\ B 173.00 \\ 10 \text{ Int.} \end{array}$

In Spring

Clofe
On Hazle Spring
Hedge to Spring

$\begin{array}{r} 135 \\ 245 \end{array}$

$\begin{array}{r} 07 \\ 15 \end{array}$

0 8

$\begin{array}{r} 173.00 \\ 180 \end{array}$

$\begin{array}{r} >202.15 \\ B 150.45 \end{array}$

$\begin{array}{r} 353.00 \\ 150.45 \end{array}$

202. 15

$\begin{array}{r} 154 \\ 335 \\ 550 \end{array}$

$\begin{array}{r} 11 \\ 50 \\ 35 \end{array}$

720 Int.

In William

Wary's

00 Corner
Land

825

$\begin{array}{r} 150.45 \\ 180 \end{array}$

0 9

$\begin{array}{r} 330.45 \\ 90.45 \end{array}$

$\begin{array}{r} >240.00 \\ B 90.45 \end{array}$

240. 00

90

20

510

05

640

70

755

15

830

43 Corner
Spring

* Clofe

Hazle

Taken

[71]

Taken from ⑥ 6

⑦ 7

257. 30
180

437. 30
274. 45

162. 45

162. 45
B 274. 45

15 40
50 230
35 230
350 260
350

Gate
05

10 against Hedge and
Corner of Spring-clofe

R ⑩ 10

180. 00
B 274. 45

On Tho. Cole's

30 60
20 100
00 160

20
40

274. 45
180

454. 45
208. 20

246. 25

⑩ 10
> 246. 25
B 208. 20

In Tho. 10 Int.
Cole's

Land
Hedge to Spring
Clofe

300 100
340 10
370

[72]

208 20
180

388. 20
180

208. 20

180. 00

180. 00

360. 00

85. 00

275. 00

⊙ 11

> 208. 20
B 180. 00

00

630

610

18

15 Corner

⊙ 12

> 275. 00

B 85. 00

20

Corner

on Spring Close

Hedge to Spring-close

00

20 Corner

Close-spring-close

400

870

Taken from ⊙ 3

⊙ 4

340. 30

180

520. 30

353. 15

167. 15

< 167. 15

B 353. 15

On Woodfield
Hedge to Woodfield

10

10 Corner of
Long Mead

Hedge to Long Mead

Gate 20

440

00

[73]

R

⊙ 13

0 /
353. 15
180

0 /
91. 15
B 82. 00
20 Int.

533. 15
82. 00

20

In Woodfield
15 Corner of Hazel-
(Wood
Hedge to Wood
15

451. 15
360

550

91. 15

⊙ 14

82. 00
180

99. 00
B 163. 00
00

10 Gate
On Wood-Close
Hedge to woodfield
30

262
163

550

99

⊙ 15

163. 00
180

> 249. 45
B 93. 15

343
93. 15

249. 45

35
430
600
610

00 Corner
130
100
50 against Hedge and
Corner of Woodfield.
On Lord Title's Land
Hedge to Title
10 Corner

835

[74]

93. 15
180

273. 15
195. 40

77. 35

195. 40
180

375. 40
246. 30

129. 10

against Hedge 20
On Hazle Wood
Hedge to Wood

25

353. 15
180

533. 15
350. 30

182. 45

10

10

16

77. 35
B 195. 40

00 00

320 210

500 00

650 135 Corner

742

17

129. 10
B 246. 30

00 15

610

15 Corner
Close Woodfield

13

180. 00
B 353. 15

20

On Long Mead
Hedge to ditto

140

00

18

182. 45
B 350. 30

360

20

445

20

350,

$\begin{array}{r} \text{---} \\ \text{---} \\ \text{---} \end{array}$	[75]
$\begin{array}{r} \text{---} \\ \text{---} \end{array}$	$\odot 19$
$\begin{array}{r} 350.30 \\ 180 \end{array}$	$\begin{array}{r} \odot 168.30 \\ B \end{array}$

$\begin{array}{r} 530.30 \\ 2.00 \end{array}$

$\begin{array}{r} 528.30 \\ 360 \end{array}$

$\begin{array}{r} 168.30 \end{array}$

00	100	20
25	255	05
25	350	00
15	440	10
10	520	20
30	595	30
30	663	70

$\begin{array}{r} 2.00 \\ 180 \end{array}$

$\begin{array}{r} 182.00 \\ 360 \end{array}$

$\begin{array}{r} 542.00 \\ 307.40 \end{array}$

$\begin{array}{r} 234.20 \end{array}$

$\odot 20$
 > 234.20
 $B \ 307.40$

Gate 75	60	
30	170	
against Hedge 20	215	00
On But's Close		
Hedge to Close		
00	450	20

307.40
 180

 487.40
 287.00

 200.40

[76]

21
 200.40
 B 287.00

20 150
 20 260
 75 275
 380
 70 400

Gate

00 against Hedge and
 Corner of Long Mead
 On Walter's Meadow

25 510

287.00
 180

R 22
 280.40
 B 186.20
 10 Int.

467.00
 186.20

280.40

27

In Walter's Meadow
 110 Corner
 On Long Mead
 Hedge to Long Mead

360
 540
 735

15
 190
 10

[77]

186. 20
180

366. 20
166. 15

200. 05

Corner 10
On Trout Beck
Common Mead 00

River 40
166. 15
180

346. 15
111
235. 15

River 50

River 40
111. 00
180

291
229. 20

61. 40

⊙ 23
> 200. 05
B 166. 15

10 Int.

20

50

150

235

245

⊙ 24

> 235. 15
B 111. 00

40

105

255

345

460

R ⊙ 25
< 61. 40
B 229. 20

80

120

150

160

170

200

In Long Mead
Here Trout Beck
River becomes the
Fence.
River 40

30

35

50

40

[78]

111. 00
180

291
162. 30

128. 30

River 30

162. 30
180

342. 30
251. 30

91
River 40

251. 30
180

431. 30
290. 30

141. 00

River 30

River goes off

15
50
10
30

45
00

67
70
15

⊙ 25

> 128. 30
B 162. 30

145
190
430
535
585

⊙ 26

< 91. 00
B 251. 30

70
175
270

⊙ 27

< 141. 00
B 290. 30

o

205
280
360

River 60

at

this place

[79]

290. 30
180

470. 30.
179. 30

291. 00

On Tho. Cole's
Hedge to Cole

10

10

20

10

10

28

> 291. 00
B 179. 30

00

150

300

400

510

Clofe Long Mead

22

< 180. 00
B 287. 00

In
Corner 00

Roughton

Common

30

65

287. 00
180

467
2. 10

464. 50
360

104 50

On But's Clofe

Hedge to Clofe

86

00

65

29

< 104. 50
B 2. 10

230

480

635

$\begin{array}{r} 0 \quad 1 \\ 2. \quad 10 \\ 180 \\ \hline 182. \quad 10 \\ 93. \quad 10 \\ \hline 19. \quad 00 \end{array}$

$\begin{array}{r} 93. \quad 10 \\ 180 \\ \hline 273. \quad 10 \\ 167. \quad 10 \\ \hline 106. \quad 00 \end{array}$

$\begin{array}{r} 167. \quad 10 \\ 180 \\ \hline 347. \quad 10 \\ 220. \quad 30 \\ \hline 126. \quad 40 \end{array}$

[80]

⊙ 30

$\begin{array}{r} 0 \quad 1 \\ \angle 89 \quad 00 \\ B \quad 93. \quad 10 \\ 65 \text{ Int.} \\ \text{In But's Close} \end{array}$

$\begin{array}{r} 100 \\ 350 \\ 750 \\ 835 \end{array}$

On Roughton Com.
 65 Hedge to Close
 100
 100
 15

$\begin{array}{r} R \quad \odot \quad 31 \\ \angle 106. \quad 00 \\ B \quad 167. \quad 10 \\ 0 \\ 590 \end{array}$

20 on Home Close
 Hedge to H. Close
 15

$\begin{array}{r} \odot \quad 32 \\ \angle 126. \quad 40 \\ B \quad 220. \quad 30 \\ 0 \\ 85 \\ 415 \end{array}$

10
 10 against Hedge
 On Hazle Wood
 Hedge to Wood
 10
 close But's Close

$\begin{array}{r} \odot \quad 31 \\ \angle 180. \quad 00 \\ B \quad 93. \quad 10 \\ 20 \text{ Int.} \\ \text{In Home} \\ 195 \\ 195 \\ 750 \end{array}$

Gate
 Close
 On Roughton Com.
 30
 75
 10

[81]

R

93. 10
180

273. 10
180. 30

92. 40

180. 30
180

360. 30
238. 20

122. 10

238. 20
180

418. 20
308. 30

109. 50

Taken from © 31

93. 10
180

273. 10
102. 00

171. 10

© 33

92. 40

B 180. 30
00

625

735

© 34

122. 10

B 238. 20
00
310

© 35

109. 50

B 308. 30
00
485

© 33

171. 10

B 102. 00
20 Int.

In Mottle
300
315

On Mottle Mead
Hedge to Home Close

15 against Hedge
On Hazle Wood
Hedge to Wood
20

10

10

10

10

close Home Close

Mead
On Roughton Com.
25

G

102

$\begin{array}{r} 6 \text{ ' } \\ 102. \text{ CO} \\ 180 \\ \hline 282. \text{ CO} \\ 82. \\ \hline 200. \end{array}$

$\begin{array}{r} 0 \text{ ' } \\ \odot 36 \\ > 200. \text{ 00} \\ B 82. \text{ 00} \\ 70 \\ 150 \\ 380 \\ 600 \\ 770 \\ 808 \end{array}$

65
 10
 60
 15
 15
 10

$\begin{array}{r} 82. \text{ 00} \\ 180 \\ \hline 262. \text{ 00} \\ 125. \text{ 30} \\ \hline 136. \text{ 30} \end{array}$

$\begin{array}{r} \odot 37 \\ < 136. \text{ 30} \\ B 125. \text{ 30} \\ 00 \\ 100 \\ 260 \end{array}$

15
 30
 30 against Hedge

$\begin{array}{r} 125. \text{ 30} \\ 180 \\ \hline 305. \text{ 30} \\ 201. \text{ 50} \\ \hline 103. \text{ 40} \end{array}$

$\begin{array}{r} \odot 38 \\ < 103. \text{ 40} \\ B 201. \text{ 50} \\ 00 \\ 255 \\ 270 \end{array}$

On Lord Title's Land
 Hedge to Lord
 60

R

$\begin{array}{r} 201. \text{ 50} \\ 180 \\ \hline 381. \text{ 50} \\ 279. \text{ 20} \\ \hline 102. \text{ 30} \end{array}$

$\begin{array}{r} \odot 39 \\ < 102. \text{ 30} \\ B 279. \text{ 20} \\ 00 \\ 295 \\ 605 \\ 620 \end{array}$

30 On Hazle Field
 Hedge to Mottle Mead
 35
 15 Corner

[838]

279. 20
180

459. 20
177. 15

282. 05

177. 15
180

357. 15
271. 50

85. 25

⊙ 40

> 282. 05
B 177. 15

370

10

⊙ 41

< 85. 25
B 271. 50

00

15

235

15

R

⊙ 42

> 180. 00
B 271. 50

20

15 against Hedge
On Hazle Wood
Hedge to H. Wood

375

15
close Mottle Mead

271. 50
180

451. 50
183. 00

⊙ 42

> 268. 50
B 183. 00
15 Int.

268. 50 In
On Hazle Wood
Hedge to Wood

Hazle Field

25
Corner 10

375
760
790

[84]

183. 00		0 43	
180		0 1	
363.		< 153. 30	
209. 30	270	B 209. 30	
153. 30		230	
Corner 00		445 Int.	
In 25		Wood	Close
Corner of 30		650	
Hazle Wood		860	
and Woodfield			
Taken from 0 38		0 39	
201. 50		> 196. 35	
180		B 185. 15	
381. 50		30	20 Corner
185. 15	In	30 Int.	Field
193. 35		Hazle	On Ld. Title's land
			Hedge to Lord
		400	165
		365	100
		1100	10
		0 44	
185. 15		> 193. 45	
180		B 171. 30	
365. 15		200	110
171. 30		345	30
193. 45		440	70
		520	20

[85]

0
171. 30
180

351. 30
270. 30

81

270 30.
180

450. 30
338. 00

112. 30

close Hazle Field

R

⊙ 45

< 81. 00

B 270. 30

15

100

340

650

740

990

45 On Wood Close
Hedge to Wo. Close

65

95

75

80

13

⊙ 46

< 112. 30

B 338. 00

00

200

10

15 against Hedge
On Hazle Wood

⊙ 45

> 180. 00

B 171. 30

15

35 Int.

In

Wood

255

300

10 Corner
On Ld. Title's Land
Hedge to Lord
Close

30

G 3

171

[88]

171. 30
180

351. 30
251. 00

100. 30

0 47
100. 30
B 251. 00

25 100
240 230
330 175
310 125
640 00
680

120 against Hedge
On Woodfield



SECT,

S E C T. VII.

To protract the observations contained in the preceding Field-Book.

FIRST, draw parallel right lines, as those in plate II. marked NS, representing meridians or north and south lines, at a distance from one another, not exceeding the breadth of the diametrical part of the Protractor.

Then picking out some convenient place to represent the first station, as A; the field-book being open before me, I lay the center of the Protractor on the point A, and the diameter parallel to the lines NS, and the beginning of the degrees downwards, because the bearing is more than 180; then against 327 degrees, I make a mark with my Protracting Pin, to which I draw an obscure line from A, representing the chain-line from the station A to the station B.

Then to this obscure line, I lay the edge of my Plotting Scale, the beginning of the divisions coinciding with A, and increasing towards the next station B, and because the off-sets, in the first length, are taken at the distances 65, 345, 520, 540, 800, 825; therefore, against these numbers on the scale, I make marks in the obscure line close to the edge of the scale.

This done, I turn my scale perpendicular to the obscure line, and apply it successively to these several points, and there prick off the lengths of the se-

veral off-sets on their respective sides of the obscure line; so at A, I prick off 20 on the right hand, and 20 on the left; at the length 65, which is the next point, I prick off 25 on the right hand, and 20 on the left; and at the next point, which is at the distance 345, I prick off 50 on the right hand, and 40 on the left; at the fourth point, which is at the distance 520, I prick off 00 to the left hand; at the fifth point, which is at the distance 540, I prick off 50 to the right hand; at the next point, which is at the distance 800, I prick off 00 to the right hand, and 40 to the left; at the last point, because no off-set was taken, I lay none down.

And now, if lines are drawn from point to point on each side of the obscure line, they will represent the fences as was required. But when the off-set is 00, as in the fourth and sixth distances, those points, to prevent being over-looked, should be marked with a black-lead pencil, or something else, which may be easily rubbed out again.

At the second distance, where we were against the south fences of Woodfield and Hazle Spring, with a black-lead pencil draw two short lines, cutting the lane, to denote that the south fences come up to the lane, and will hereafter be of use in closing these plots.

Having thus finished my first length, I produce it, if occasion require from B. both ways, till it is as long each way as the Radius of the Protractor. Then I place the center of the Protractor on B, and thereon turn it about, because the degrees of the next angle are more than 180, till the beginning of the degrees of the Protractor are contrary to the last station A, and the diameter coincident with AB. Then close to the edge of the Protractor, right against $202^{\circ} 45'$, I make a mark with my Protracting Pin, and to it from B draw an obscure line representing the chain-line from B to C.

Then

Then I turn the Protractor about, the center still coinciding with B, and because the bearing is more than 180, set the beginning of the degrees towards S, and the diameter parallel to the meridians; and then, if you have truly wrought, the line BC before drawn, will meet the limb of the Protractor against $304^{\circ} 15'$, the bearing of the line BC.

But if it doth not, the line BC is not in its true position, and must be corrected before you proceed.

Or thus; the center of the Protractor coinciding with B, I turn it about till the beginning of the degrees is towards S, because the bearing is greater than 180, and till the diameter lies parallel to the meridians; and then close to the edge of the Protractor, with my protracting Pin, I make a mark against $304^{\circ} 15'$, the bearing of the line DC, and to it from B, draw a strait line representing the strait line BC. Then turning the Protractor about on the center C, and because the angle there taken was $202^{\circ} 45'$, or more than 180, I turn the beginning of the degrees of the Protractor contrary to the last station A, and the diameter to agree with AB; and then will BC meet the limb of the Protractor against $202^{\circ} 45'$, if the bearing is truly down.

And thus the plot may be laid down by the bearings, and examined by the angles.

Then to this obscure line, I apply the end of my Plotting Scale, the beginning of the divisions coinciding with the present station B, and the numbers increasing towards the next C; and then close to the edge thereof, against 240, 250, the lengths where the off-sets were taken, I make marks with my Protracting Pin. This done, I turn my scale perpendicular to the obscure line, and at 240, I prick off 15 to the left hand, and against 250, which gives the point C, I prick off 10 to the right hand, as the field-book directs. Now continuing the fences

to

to these off-sets, I shall have finished the second length from B to C.

The second length thus finished, I produce it, if occasion require, from C both ways, till the length each way be at least equal to the Radius of the Protractor. Then I place the center of the Protractor on C, and because the degrees of the angle at C are less than 180, I lay the beginning of the degrees of the Protractor towards B, the last station, and the diameter on BC. Then close to the edge of the Protractor, with my Protracting Pin, I make a mark against $143^{\circ} 45'$; the quantity of the angle at C, and to it draw an obscure right line from C, representing the line from C to D.

Then turn the Protractor about, its center still coinciding with C, because the bearing is more than 180, the beginning of the degrees towards S, and the diameter parallel to the meridians; and then if you have worked truly, the line CD before drawn, will meet with the limb of the Protractor against $340^{\circ} 30'$, the bearing of the line CD.

But if not, the line CD is not in its true position, and must be corrected before you proceed.

From the laying down these two angles and bearings, it appears how errors often happening in practice, may be prevented.

The general rules I observe herein are three, viz.

1. I lay the diameter of the Protractor on that line which brought me to the present station, where the angle, about to be laid down, was taken.

2. I lay the beginning of the degrees of the Protractor towards the last station, when the angle is less than 180 degrees; but the contrary way, when the angle is more.

3. In laying down or examining the bearing, I lay the beginning of the degrees of the Protractor northwards, when they are fewer than 180; but southwards, when more.

In like manner I lay down and examine the angles and bearings taken at D, L, M, N, O, Q, the 4th, 5th, 6th, 7th, 8th, 9th stations, and also the corresponding lengths and occurrences. But in the last length QA, having at the length 830 laid off an off-set of 43, it gives exactly that corner of Hazle-spring, which was noted down in the first length in the lane; which proves that the angles and lengths inclosing Hazle-spring, are truly laid down. But if the extremity of the last off-set in the length QA doth not coincide with the extremity of the second off-set AB, both denoting the south west corner of Hazle-spring, the lengths and angles designed to inclose the same Hazle-spring, are not truly laid down, and therefore must be examined and corrected before you proceed.

Now $\odot 7$, being marked with 7, a number not greater than 9, the number of the last station, being the next work noted in my field-book, I return to $\odot 7$ in my draught, and there with MN, the line which I measured immediately before I came to N, I make the angle MNR $162^{\circ} 45'$, and the bearing NR $274^{\circ} 45'$, as noted in the field-book, and then proceed to lay down the off-sets and other occurrences, at their proper lengths and distances.

Having finished NR, I find next following in my field-book $\odot 10$, which because it is greater than 8, the number which immediately follows 7, the number of the last station; and because I find no station already laid down, marked with a number so great as 10, therefore I conclude, that the station R, where I now am, is to be numbered 10; and from thence proceed

proceed to lay down and examine the angle and bearing at R, as usual.

The rules I observe in these cases are,

1. To number with black lead all the stations I have already laid down in my draught, and also to express those numbers successively after one another, in a piece of waste paper, which I examine as often as I please.

2. If I come to a station whose number doth not immediately succeed the number of the last station, but is greater than the greatest of those numbers noted in my waste paper by an unit; then at the station now arrived at, I lay down and examine the bearing and angle with the line I measured immediately before I came to this station. And this station I number as denoted in my field-book.

3. If I come to a station, whose number doth not immediately succeed the number of the last station, but is greater than the greatest of those numbers noted in my waste paper by more than an unit, then some omission hath arose in my waste paper, and must be rectified before I proceed.

4. And lastly, if I come to a station whose number is already entered in my waste paper, then I return to that station in my draught, and there lay down and examine the bearing and angle with the line, measured immediately before I came to this station the first time.

Now the next observation I meet with in my field-book, is again $\odot 10$; therefore again at $\odot 10$, I lay down and examine an angle and bearing, as noted in the field book, and then proceed to lay down

down the lengths and off-sets of the line RS, as I find in my field-book.

Being come to S, I proceed to T; and from T to P, there closing with the extremity of the off-set at P, coinciding with the south-west corner of Spring-close, and the south-east corner of Hazle-spring.

This done, I find next in my field-book $\odot 4$; therefore I return to $\odot 4$, and there proceed as my field-book directs, till I come to station 13; and because this is a number greater, by an unit, than 12, the number noted in my waste paper, I number it 13, and then proceed, as my field-book directs, to F, G, H, I, and K, there closing in Woodfield by the extremity of the off-sets there laid down.

This done, I next find $\odot 13$, and therefore, because already entered in my waste paper, I return to $\odot 13$ in my draught; and then proceed as before shewn, till I have plotted all the occurrences mentioned in my field-book: but the remaining part hereof I leave for the exercise of the reader.

All houses, barns, mills, or other buildings; also kilns, stone-pits, gravel-pits, ponds, watercuts, hills, hollow-ways, land-marks, bridges, roads, bridle-ways, foot-ways, stiles, remarkable old trees, and any other particular which the surveyor may meet with on the estate he is working in, should be noted in the field-book; and such measures, and sketches of them taken, as that they may be inserted in the plan: for such particulars being frequently referred to in old terriers of estates, their being accurately delineated in a map, would ascertain their position and distance from other places; and thereby prevent some of the fatal contests that arise among neighbouring families.

When all the particulars contained in the field-book are delineated or mapped, cast up the contents of each inclosure, road, lane, waste, &c. by the methods before shewn; and write the contents, together with

with the name in each piece: let the plans of buildings be shaded by lines drawn across, and write the names of the neighbouring estates or parishes on the outside, near the places where they bound the lands in your map; also at the ends of roads and lanes, write where they lead to and from; and thus will the foul draught of the survey be finished. This foul draught may be transferred to your clean paper, parchment or vellum, many ways; among which the following one is easily practised.

Take the scrapings of red chalk and black lead, in equal quantities, mixed together; rub the black of the map with this powder, and then wipe off as much as will come away with gently rubbing a cloth over it: lay this coloured part downwards on the paper or vellum, fastening them together with weights, pins, &c. Then with a sharp-pointed bodkin or tracer, trace all the lines of the survey, and the impression of them will be marked on the vellum: take the foul draught off, and go over all the coloured lines with a fine pen and Indian ink; and so will the draught be transferred.

Annex a scale of poles and yards, with a compass, allowing for the variation of the needle; also insert the latitude of the church, manor-house, or some other noted mark; and embellish the map with such other ornaments as are commonly introduced in works of this kind.

Observe that the representation of the hedges ought to be laid down on the same sides of the fences, that they are in the land; and to be broke off where there are to be the representations of gates, &c.

There ought to be imaginary lines, both vertical and horizontal, denoted by letters placed at the top and bottom, and also on the sides, to be referred to by the table of references; for the ready finding any field, or parcel of land therein contained.

Lastly,

Lastly, I shall, in this place only add, that in all performances of this kind, errors, for the most part, arise from the defects of instruments, in the framing, dividing, and contriving.



SECT. VIII. *

Of a new, certain, and expeditious method of surveying and plotting by the Theodolite, as now improved.

IN the practice of surveying, it hath hitherto been found very difficult to make a large parcel of land, when it came to be laid down in a map, close exactly with regard both to the lines and angles measured, especially if it were mountainous and hilly ground, nay even a small quantity of uneven land has often puzzled those who otherwise thought themselves expert surveyors. Now this difficulty in closing the draught, arises chiefly from the following causes.

First, The not taking care to place the plane of the instrument truly horizontal or level, and which indeed it is almost impossible to do by the eye alone, especially on the side of a hill; and tho' this may by some be thought of little signification, yet those who have any knowledge in geometry, must allow, that very great and unavoidable errors will arise thereby; for it may be demonstrated, that if the plate of the instrument dip but 2 degrees at right angles to the line of observation, and the hill descend 10 degrees, it will cause an error of 42 minutes in the

* This Section is part of Mr. Warner's Appendix to the second edition of this book.

angle,

angle, and the object will be thrown out of its true place 12 links in the distance of 10 chains; and how great confusion must this make in plotting the succeeding angles which turn thereon as on a center? But if so considerable an error arise by missing the level only 2 degrees; nearer than which I believe no one will pretend to place an instrument with by his eye, what egregious blunders must the practisers with the plain table make, who, when they cannot see thro' the sights of their instrument on an ascent or descent, do commonly rise, dip, or, as it may be properly said, twist the plane of their table more or less out of the level till they can see their objects?

Secondly, The not making due allowance for the difference between the lines of ascent or descent, and the horizontal lines, which are the only lines that ought to be laid down; and though it is a common practice on the side of a steep hill, to double the chain, and so in ascending to make the leader hold the middle in his hand close to the ground, while the follower raises the end by the staff in his hand, till he judges it to be strained on the level, and in descending, the leader elevates the middle by his staff in like manner, while the follower keeps the end close to the ground; yet a true horizontal line can hardly be obtained this way, by reason of the swaying of the chain, and the uncertainty of keeping it in its due place.

Thirdly, The plotting the angles by removing the Protractor from station to station; in doing which, if we consider the nicety required in laying the diameter of the Protractor, and the variation of the hand in pricking down the quantity of degrees and minutes, and in drawing the station-lines, we must allow it to be a very difficult matter to protract so near as 10 minutes; whence, if there be a considerable number of stations in the circuit, the plot will rarely be found to close as it ought, for an error in
any

any one of the angles will be communicated to all that follow, and each succeeding station will be thrown more and more out of its true place, as it is farther from the angle where the error first arose; and though it be a good way to protract backwards as well as forwards, yet even that will hardly bring it to bear, unless the errors happen to counter-balance.

The foregoing are the principal causes that render it difficult to make a correct map; and they are now entirely obviated by the New Improved Theodolite, as made by Mr. HEATH, and the method of surveying and plotting hereafter described.

First, This instrument has a spirit-level affixed to the telescope, and another spirit-level at right angles thereto in the box; by means of which cross levels, and the help of four screws playing between two plates in the brass head of the staff, the plate or limb of the instrument is readily brought to a true horizontal situation.

Secondly, The telescope, with cross hairs therein, turns on an arch fixed to the index perpendicular to the plate of the instrument; the arch is of the same radius as the plate, and the telescope may be elevated or depressed thereon quite to a quadrant, or 90 degrees. On this arch are graduated the degrees of a circle, which are numbered from the vertex either way, with 10, 20, &c. and are cut by an index under the telescope, divided after Vernier's (commonly called Nonius's) Way, like those on the limb of the instrument. Within the degrees are two lines numbered with 10, 20, &c. down to 100, and cut by the edges of the index; on the right whereof is graved Elevation, and on the left Depression. These lines serve to shew the altitude or depression of any object in 100th parts of the distance at which the instrument is planted to take the observation, and are useful in finding the height of a tree in the measuring

of timber standing; as also to find the altitudes of the several parts of a building in drawing the perspective appearance thereof, as will hereafter be shewn. Below these are other graduations cut by the lower part of the index, which shew the difference between the hypotenuse and base of any right-angled triangle, (the hypotenuse being always supposed to consist of 100 equal parts) and consequently they give by inspection the number of links to be deducted out of each chain's length in going up or down any hill, for reducing the hypotenusal lines to horizontal. There are also plain sights fixed upon the telescope to be used in short distances, and for continuing the same strait line both ways from the instrument, as is necessary to be done in many cases.

When the index under the telescope is set to 00° at the vertex of the arch, and the two bubbles brought to the middle of their tubes, then the horizontal hair in the telescope cuts an exact level, and the plate of the instrument becomes a true horizontal plane; and if the intersection of the cross hairs be set to any object by moving the telescope above or below the level, the divisions on the vertical arch will shew the elevation or depression of the object: also, when the telescope is directed to any object, the instrument may be readily fixed so firmly in that direction, by turning a screw under the center, that there can be no danger of being stirred by removing the index on the plate towards another object. The degrees on the plate are divided so accurately, that though they are cut by three indices 120° distant from one another, having Vernier's (or as vulgarly called, Nonius's) divisions on each, yet the eye can perceive no inequality in the divisions all round the limb, but whatever part of a degree the index under the eye-glass of the telescope cuts, the same will always be found to be cut by the other two; there is
also

also a small index that serves to cut the particular divisions on the limb to be used for taking the breadths in drawing the perspective appearance of any building. The whole index, with the box fixed thereon, turns round on a conical center without stirring the needle, and may be fixed to any part of the limb, by means of a spring and screw adapted thereto. In a word, the entire instrument is contrived so commodious, portable and strong in all its parts, that it is allowed to be the best of the kind ever yet made.

Thirdly, In order to avoid any error that may arise in taking the angles in the field, or from protracting them angle by angle, as has hitherto been the universal custom, let the surveyor observe this following method, which for its readiness as well as accuracy, will, no doubt, be preferred and practised by all who would excel in this art.

The instrument being planted at the first station, fix the index to 360 degrees on the limb, and setting the plate truly horizontal, turn it about till the south end of the needle hangs over the Fleur-de-lys or 360 in the box, and fix it in that position by help of the screw underneath; then discharging the index, turn that about, and direct the vertical hair in the telescope, to cut the second station; there fix the index to the plate again, and the south end of the needle will shew the bearing of the first line, which will also be cut by the index on the limb, and is to be entered in the field-book, as before shewn. Now, when the instrument is removed and planted at the second station, observe that the index hath not been stirred, and turning the whole limb about, direct the vertical hair in the telescope back to cut the first station, fix the plate in that position; then discharging the index, turn it about till the same hair cuts the third station; there fix the index to the plate again, and set down the number of degrees and minutes it cuts on the limb, which number will at the

same time be cut by one end or other of the needle in the box, if there be no mistake in the observation: proceed in like manner at the third and all the following stations, always remembering after you have turned the plate about, and directed the telescope backwards, to observe that the index remains fixed at the degrees last noted in the field-book, so will the needle be always found to correspond with the index sufficiently near, to discover and prevent any error in the work.

We have here added an example of part of the field-book of an actual survey, wherein the angles were observed by the method above described; and though there were 24 stations in the circuit, yet for proof, the instrument being planted again at the first station, and the telescope directed back to the 24th, the plate being fixed in that position, the index was discharged, and the telescope directed to the second station, and then the index cut the same number of degrees as was first set down in the field-book.

When there is occasion to return to some former station, in order to go off from thence for the closing some particular part, as in the following example, we return to station 23. Enter the number of such station again in the field-book, with a small figure at the head of it, denoting how often the instrument has been planted at that station, thus 23² denotes the second time of planting the instrument at station 23; then consider from which station you looked forwards to the present station 23, which was station 22; seek in the field-book the bearing of the line between the stations 22 and 23, and fix the index to that number on the limb; then turning the plate about, direct the telescope back to the former station 22, fix the plate in that position, and discharging the index, direct the telescope forwards to the next station, and thence proceed as before; so will the needle be always found to be a sure cheque

on the limb, tho' the observations do not depend thereon.

Note, The letters affixed to the numbers of the stations in the following Field-book, are not to be used in practice, being here added only for the more easy referring to the plot, in describing the new method of laying down.

The plan to which the following Field-book refers, is in Plate III. By the mark $\times$ is understood an intersection, either across a gate or fence. When against an off-set is put the mark $+$, and another number follows it, it means that both the numbers are to be laid off on the off-set line. $\angle$ signifies an angle or corner.



FIELD-BOOK of Part of the Manor of R. &c.

Remarks, Left.	Offsets Left.	⊙ s Bearings Lengths.	Offsets Right.	Remarks, Right.
		⊙ 1 (A)	- - -	Upon Warley Common
		0 1		
Bearing - - - -	- - -	43:20	- - -	N ^o Ely
Hedgebutts to Kiln Wo.	20	11		
Against Kiln Wood	27	59		
Hedge to ditto	31	165		
		⊙ 2 (B)		
⊲ + last Bearing - - -	- - -	204:40		
	30	175		
	15	280		
	30	400		
	21	560		
	14	746		
Hedgebutts to Furzfield		766		
		⊙ 3 (C)		
Against Furzfield - -		17:12		
	9	50		
	1	100		
	3	200		
	21	365		
		446	⊙ for	closing Furzfield and
Hedgebutts to Furzfield	27	470		entrance of the Lane
agst. upper Poundfield	30	520		to Brentwood.
		⊙ 4 (D)		
		195:50		
	46	140		
Hedgebutts to Woodga	41	255		
Depth of the gard. 216				
Pound begins, and	48	500		
Fencebutts ends	46	527		
		560		

		⊙ 5 (E)	
		268:20	
↖rs Pound - - -	{ 15	50	x Gate into Pound Lane
	7	65	37 to Gate into Lower Pound Field
Woods House 30 deep	{ 35	97	
	20	114	
		165	
↖r of Woods Garden	24	225	75 Hedgebutts to Lower Pound-field against Pondfield
113 deep, and Hedgebutts to upper Pound-field		272	
		300	32
		330	20
Gate - - - - -	20	350	
	28	383	20
		444	23 Hedgebutts to Cow-house-field
	15	465	
	12	483	25
		⊙ 6 (F)	
		107:50	
Gate - - - - -	6	58	26 Gate
Hedgebutts to Upper Poundfield against little Boggyfield	12	155	
		200	29 Hedgebutts to Cow-house-field against the Hoppit.
		222	16
Gate - - - - -	42	238	- - - Gate
	6	300	22
		⊙ 7 (G)	
		332:15	
	15	26	13
		170	6
Lane returns - - -	21	186	
		200	⊙ for the Return No 32.
↖r against Gravel-pit-field	7	247	10 x Gate into Moor's Barnfield
Hedge to Barnfield -	7	267	

		⊙ 8(H)	
		166:20	
Ponds begin in Gra-	12	190	
vel-pit-field	30	250	
	39	265	
	30	300	
		379	
		⊙ 9(I)	
		324:35	
Ponds end - - -	40	27	
Gap - - - - -		118	
Fence changes to Gra-	60	200	
vel-pit-field	58	317	
	9	457	
	2	535	
	9	586	
		698	
Gate - - - - -			
From bye ⊙ at 330		⊙ 10(K)	
in line 11, 12.		40 : 50	
319 to ⊙	50 10	20	34 × Gravel - pit - field
N ^o 11.	330 23	165	45 Hedge into ditto,
	380 10	380	12 against Home-field
	100 6	520	24 Hedge to ditto
	280 0	744	58 Hedgbuts to Dungfield
	315 30	791	- - - Gate
	351 10		
	130 4		
	170 6		
	286 58		
	375 69		
	440 0		
	480 0		
Kiln } 195	494	67	64
field } 120	550	84	75
	568 × Hedge &	250	75
	Brook into Alders	330	bye ⊙ for the Alder Ground
	Cumber's	340 × into	Alder Ground
	698 × hilly	473	27
	FieldHedge	493	× Hedge & Brook into
	720 to ⊙ 13	505	Cumbers's-Lane.

		⊙12(M)		
		355:50		
To the Brook - - - -	24	90		
	46	157		
		178	111	to Cumbers's Garden Hedge.
	42	236		
	62	275		
			+into	Cumbers's Alder grou.
		308	45	to Gate + 60 to ∇ r Homsted.
		347	51	to ∇ r Hillyfield Hedge
	75	357		
	75	427		
		480	+into	Hillyfield.
		535		
		⊙13(N)		
		165:25		
To Hillyfield Hedge	43	77		
Against Alder Ground	42	100		
	50	117		
	60	170		
	53	267		
To Alder Hedge 45+	45	312		
	11	396		
To Al.hed. 81+Corn.	7	446	+hily	field Hedge into Boggy-field.
		489		
		⊙14(U)		
		319:25		
To Alders - - - - -	30	13		
To Kilnfield Hedge	128	40		
To Alders - - - - -	25	120		
To hunting gate 55+	30	155		
Point of the Island 59+	30	200		
		229		

111 to Cumbers's Garden Hedge.

+into Cumbers's Aldergrou.
45 to Gate + 60 to $\swarrow$ Homsted.

51 to $\swarrow$ Hillyfield Hedge

+into Hillyfield.

+hily field Hedge into Boggy-field.

		⊙15(P)	
		179:55	
Against Island - - - -	43	8	
Fence to ditto - - - -	25	75	
	21	237	Bogs.
	37	345	
	25	464	
	16	484	
		⊙16(Q)	
		33:20	
	17	50	
Corner - - - - -	13	188	
		⊙17(R)	
		280:50	
Hedge to Boggyfield	15	00	
Woodland ends - - - -	18	79	
	15	148	
		177	
		⊙18(S)	
		347:50	
		19	x
Against Acre Bit - - -	16	240	Boggyfield Hedge to Broomfield.
		388	
		⊙19(T)	
		27:25	
		74	x
To Alders - - - - -	40	150	Acre Bit Hedge to dit.
To Hedge - - - - -	57	194	
		241	
		⊙20(V)	
		256:35	
To Hedge 15 + - - -	5	00	
25 + - - -	10	100	

To Hedge - - - - -	15	198	x	Acre Bit-hedge into
Against woody ground	19	260		Little Broomfield
Hedge to Lit. Broomfi.	50	383		
		⊙21(W)		
		90:30		
	60	72		
Bogs - - - - -	70	163		
	75	340		
		395		
		⊙22(X)		
		290:10		
	49	20		
Against Kilnfield Gate - - -		176		
		⊙23(Y)		
		104:00		
Corner - - - - - 5 +	14	35		
Against Kiln Wood	12	103		
Hedge to ditto		183		
		⊙24(Z)		
		311:10		
	5	00		
	15	63		
	6	163		
	8	243	x	Hedge into Warley Co.
		263		To ⊙ 1 where the
				∟ from the last Bear-
				ing to ⊙ 2 was found
				to be 43°:20' as at
				first setting out.
Return - - - - -	⊙	23 ² (Y,		against Kilnfield Gate.
		190:10		
		27	x	Gate into woody Gro.
				into Kilnfield.
		100	35 x	out of Wood into field
		180	26	ag. Kilnw. H. to ditto

	324	12	
	465	26	
	510	55	
	580	72	
	630	55	
	690		
	⊙ 25(a)		
	84:40		
	37	18x	into Boggy Wood H.
	80	15	to ditto.
	246	23	
	⊙ 26(b)		
	284:40		
	50	33	
	170	50	
	209	x	into Furzfield Hed. to dit.
	224	53	
	⊙ 27(c)		
	105:30		
	100	27	
	190		to Corner clofe Kiln.W.
Return to	⊙ 25 ² (a)	---	in Kilnfield.
	349:30		
	30	33	against Boggy Wood.
	90	15	
	280	37	
	396	---	Hedgebuts to Little Boggyfield.
	424		
	⊙ 28(d)		
	252:50		
	34	x	BoggyfieldHedge into
	120	45	ditto.
	200	42	
	291		

Strait Hedge to Pound Lane	-	-	-	⊙ 29(e)			
				79:30			
				100	35		
				161	x	Upper - Poundfield Hedge into ditto	
				190			
				⊙ 30(f)			
				325:12			
				50	28		
				158	x	Furzfield Hedge into ditto	
				187			
				⊙ 31(g)			
				184:00			
				35	30	Corner	
				65	45		
				300	25		
				428	to ⊙	27 close Boggy Wood	
Return to - - -	⊙	31 ² (g)					
	100	80					
		314	to ⊙			for closing Furzfield in Line 3, 4. against Gravel-pit field Hedge to ditto	
Ret. to ⊙ for the return of Pound-lane at 200, in line 7, 8 }	⊙	32 (h)					
		68:20					
		147	29				
		200	- - -	Alders			
Hedgebutts to little Boggyfield	11	212	25	x	Gate into Kilnfield		
		237	- - -	Alders end			
		306					
Stile in Boggyfield Hed	110	⊙ 33 (i)					
		172:08					
		118					
		78	390		Pond		
		56	454				
		28	574				
	43	615					
		670	to ⊙	28	close litt. Boggyfield		

Return to - - - - -	⊙	33 ² (i)	
		319:55	
		20	x Gravel-pit-fieldHedg.
		40	69 into ditto against Ald.
		173	40
		200	0
		320	11
		400	45
		500	45
		535	25
		600	27
		629	
		⊙34(k)	
		232:05	
		43	5
		106	5
		144	
		⊙35(l)	
		141:35	
		56	6
To Kilnfield - - - - -		627	10 Close Alders.
Return to - - - - -	⊙	23 ³ (Y)	
		161:30	
		170	x out of Wood into Kila-
Against woody ground	55	250	field.
	60	380	
		412	
		⊙36(m)	
		350:05	
		72	70 Kilnfield.
		68	230
		15	300
Corner - - - - -	15	595	
		633	

	90	$\odot 37(n)$ 76:10 170 458	
Passage to Island - - -	30	$\odot 38(o)$ 181:48 50 165 256 390 455 520 570 594	x into Woody Ground x Rill. 85 x into Island. 80 70 Corner. To the top of the Island
Return to - - - - -	$\odot$	$38^2(o)$ 357:00 371 451 473	x Kilnfield Fence into rough Ground. x Gravel-pit field Hedge into ditto.
Close Gravel-pit field		$\odot 39(p)$ 235:55 348 474 519 674 707 765	15 Railsbutt + 61 to rough Ground Fence 15 } Kilnhouse 33 deep + 16 } 35 to Fence. 26 } 27 } Workhouse 65 deep. x line 32, 33 close Kiln field.

Now to protract the foregoing observations, thro' the middle of the paper designed for the draught, draw the right line NS for a meridian, Plate III. and therein chuse a convenient point C, to which lay the center of a circular Protractor, the diameter coinciding with the line NS, and the 360, or beginning of the degrees being towards N the north, fix the Protractor in that position by laying a weight thereon, or pinning it down; then on the circumference of the Protractor prick down the several bearings noted in the field-book, numbering from the north eastwards, or towards the right hand all round, and to each point affix the number of the station to which it belongs.

Chuse a convenient place on the paper for the first station, as at A, and laying the edge of a parallel ruler to the center C, and the point marked 1, open the ruler till the edge cuts the point A, and thereby draw an occult line parallel to C 1, on which set off the first length (165) from A to B, the 2d station; then laying the parallel ruler to C and the point 2, transfer it to B, and thereby draw an occult line, on which set off the second distance (766) from B to C, the third station: Again, lay the parallel ruler to C, and the point 3, transfer it to C, through which draw an occult line, and thereon set the third distance (520) from C to D the fourth station. Proceed in like manner all round, and if the work be true, the last line will pass through the first point; but if it doth not, and the error arises by mistaking a whole chain or so, it may readily be discovered in which line it was committed by observing whether the last point fall short of, or beyond, or above, or below the first point with which it ought to coincide.

The only seeming difficulty that can arise in drawing the station lines by this method, will be to distinguish between an inside and an outside angle, though

though this can seldom be any obstacle to the surveyor who took the dimensions, and who by the idea he has of the land, will, for the most part, remember whether he turned off to the right or left at such or such a station; yet, if he should at any time doubt, as it may perhaps happen when he has several days work to protract, and a multitude of short stations therein: Or, if any person who never saw the land, should attempt to draw it out by the field-book, and find himself at a loss about the quantity of an angle; then let him subtract the bearing at the next preceding station from the bearing at the present station in question, increased by 360° , if subtraction cannot otherwise be made, and the remainder gives the present angle; which if it be less than 180° , shews that the line flowing from the station must be drawn inwards, but if more, outwards. Thus at $\odot 17$ noted with R; it might be doubted, whether the line from thence should be drawn inwards towards f , or outwards towards S ; to solve which, from the bearing at the present $\odot 17$, $280^{\circ} 50'$, subtract the bearing at the last $\odot 16$, $33^{\circ} 20'$, and the remainder $247^{\circ} 30'$ being greater than $180^{\circ} 00'$, shews that the line must be drawn outwards towards S ; the same doubt might also arise at $\odot 18$ (S), but if from the bearing at $\odot 18$, $347^{\circ} 50'$, we subtract the bearing at the last $\odot 17$, $280^{\circ} 50'$, the remainder $67^{\circ} 00'$ shews it to be an inside angle: Again, at $\odot 19$ (T) the bearing is $27^{\circ} 25'$, to which add 360° , and subtract the bearing at the last $\odot 18$, $347^{\circ} 50'$, and the remainder $39^{\circ} 35'$ shews the present angle to be an inside angle, and very acute.

When the draught is so large, that all the stations cannot conveniently be laid down about one center, the first meridian line may be prolonged, or another drawn parallel thereto, in which the surveyor may make choice of a new center where he shall think most proper, and round this he may place his re-

maining stations in like manner as before described; and thus he may chuse as many centers as he shall find necessary, but the fewer he can dispence with, the better.

Moreover, the bearings may be laid down by a semicircular protractor numbered, as it is commonly done, with a double row of figures to 360° , which some may rather chuse to use, because the limb thereof may be turned wholly towards the light, that so the divisions may be more advantageously seen; but considering the edge of a protractor is always made very thin, there can be no advantage gained thereby; besides the circular *one* is to be preferred in that it hath twice the room, and consequently, when there is occasion for laying down a great number of observations about the same center, they will be less liable to confusion. Again, the degrees on the limb of the instrument and in the box, may be numbered only to 180 , and then begin again with 10 , 20 , &c. to 180 more, by which means that end of the needle which is next the eye, will always cut the same division in the box as the index doth on the limb, and there will never be occasion to enter a bearing greater than 180° in the field-book; so a semicircular protractor numbered with a single row of figures, will serve to plot all the observations; but then there will be this great disadvantage (as well as the foregoing in point of room) that, should the surveyor forget whether any angle was more or less than 180° , he could not readily discover which to make use of; and should a person, who had never seen the land, go about to protract the work from such a field-book alone, he must be gravel'd at every station where the angle approaches near 90° or 270° , as not having any means whereby to discover on which side it is to be formed, tho' this doubt may in some measure be prevented by noting the angle in the field by the mark $\angle$, or $\triangleright$, according as it is

is within or without; yet should the surveyor put down a wrong mark, or forget to enter any (which may easily happen when a multitude of observations are to be taken, and the weather proves untoward) in such case a great deal of time may be spent before it can be ascertained whether the angle be internal or external, which is very readily known in the former method; therefore *that* must be the most preferable, since it can never be subject to any such inconvenience: And the practice thereof will be found so very easy to any person that understands the foregoing part of this book, that a farther explanation would be altogether needless.

But when the station lines are plotted by the bearings, there never can arise any difficulty concerning which way the line is to proceed from the last station; for as every station line is to be drawn in a direction parallel to an imaginary line from the center of the protractor to the direction in its circumference marked with the number of the station, therefore its position is naturally ascertained by drawing the line in that direction.

The figure in Plate IV. shews how the contents of the foregoing example of part of an actual survey was cast up; and here are likewise subjoined the dimensions and calculations; whereby it may be seen, that notwithstanding there are 10 several pieces measured separately, yet when the whole plot was reduced to the trapezium MNOP equal thereto (by Prob. 10. page 8.) the content of this trapezium was found not to differ from the sum of the several contents by half a pole, a confirmation of the truth surprizingly near.

Gravel-pit field with the
small parcel of Alders
in the middle of it
reduced to the Δ
 $a b c$

The base $a b$ } 1758
measured - - }

The perpendi- } 1078
cular from c }

14064

12306

17580

18195124

Area per } A. R. P.
Sect. 4. } 9 : 1 : 36

Subst. Ald. - - 0 : 2 : 14

Area of } 8 : 3 : 22
the field }

The Alder wood on the
west side of Gravel-
pit field reduced to
the $\Delta g b i$

Perpendicular } 598
from b - - }

Base $g i$ - - - 805

2990

47840

4811390

Content - - A. R. P.
2 : 1 : 25

The small parcel of
Alders in the middle
of Gravel-pit field
reduced to the Δ
 $d e f$.

The base $d f$ 655

Perpendicular } 179
from e - - }

5895

4585

655

1117245

Content - - A. R. P.
0 : 2 : 14

Kilnfield reduced to the
 $\Delta k l m$.

The base $l m$ - - 1825

Perpendicular } 1002
from k - - }

3650

182500

18128650

Content - - A. R. P.
9 : 0 : 23

Woody

Woody ground in Kiln
field with the island
reduced to the Trape-
zium $n o p q$.

The Diagon. $n p$ 1120
I from q 530 } *Sum*
I from o 410 } 940
44800
1008

10|5|2800

A. R. P.
Content - - 5 : 1 : 02

Upper Pound Field
reduced to the Δ
 $w x y$.

The base $w x$ - - 930
I from y - - - 464
3720
558
372

4|3|1520

A. R. P.
Content - - 2 : 0 : 25

Boggy-wood reduced to
the $\Delta D E s$.

The base DE - - 955
I from s - - - 480
76400
3820

4|5|8400

A. R. P.
Content - - 2 : 1 : 07

Little Boggy field re-
duced to the Trape-
zium $r s t u$.

The Diagon. $r t$ - 752
I from s - 380 } 680
I from u - 300 }
60160
4512

5|1|1360

A. R. P.
Content - - 2 : 2 : 09

Woods house and garden
reduced to the Δ
 ABC .

The base BC - - 375
Perpend. from A 197
2625
3375
375

7|3|875

A. R. P.
Content - - 0 : 1 : 19

Furzfield reduced to the
 ΔFGH .

The base GH - 929
I from F - - 336
5574
2787
2787

3|1|2144

R. P.
Content - - 1 : 2 : 10
I 3 Kiln

Kiln-wood reduced to
the Δ IKL.

The base KL — 1441

Perpendic. from I — 550

72050

7205

71212550

A. R. P.

Content — 3:3:34

The whole plot reduced
to the Trapezium
MNO P.

Perpendicular }
from N — } 1963

Ditto from P — 770

Sum — 2733

Diagonal MO — 2868

21864

16398

21864

5466

781318244

A. R. P.

Content — 39:0:30

as on the right.

The CONTENTS.

Gravel-pit Field } A. R. P.
with the Al- } 9:1:36
ders — — }

Alder Wood — 2:1:25

Kiln Field — 9:0:23

Woody Ground - - 5:1:02

Little Boggy Field 2:2:09

Upper Pound Field 2:0:25

WoodsHouse and }
Garden — } 0:1:19

Boggy Wood — 2:1:07

Furz Field — 1:2:10

Kiln Wood — 3:3:34

Total—39:0:30



SECT.

 S E C T. IX.

*Of surveying of Shoals and Sands, by help of
the New Theodolite.*

TH E R E are three methods whereby this may be performed; for the observations may be made either on the water or on the land. Those made on the water are of two kinds, one by the log-line and compass (as in plain sailing) measuring the course and distance round the sand; and then to be plotted as a large wood, or any enclosure taken by the circumferentor.

This method I omit for two reasons; first, because it is to be deduced from the writers of navigation; and, secondly, because the distances thus measured are liable to the errors of currents, which generally attends shoals or sands, that are near to the shore.

The second method, where there are no distances to be measured on the water, tho' still there is one inconvenience, common also to the former, because the bearings or observations are to be taken on that unstable element, (an error scarce mentioned by our practical artists) I shall briefly hint at; and so rather chuse a third, which is liable to neither of these imperfections.

Let (in fig. 30) a boat be manned out with a signal flag, a log and line, lead and line, and to observe the bearings of any land-mark, a compass with sights:

Take two or more places, as A, B, C, on the shore, from whence the boat may be seen on the several parts of this shoal.

One of the boat's crew is to sound till he finds himself on the edge of the sand, by the depth of water, and then to come to an anchor; which he is to signify to two persons on the shore, at B and C, by his signal. And then from these known land-marks, B and C, the observers are to take the bearings of the boat, and to register their observations; which, when done, they are to signify to the crew by waving a flag, or by some other signal.

And in the mean time, to prevent mistakes, let the crew take the bearings of each of these land-marks: Then weigh anchor, which suppose at D.

Then by sounding, proceed to E, and make like observations. And so at E, F, G, &c. till you have surrounded your sand.

And if in this process, you are about to lose the sight of one of your land-marks, suppose C, let your assistant at C, who, at that time, will also be about to lose the sight of the boat by signals (before-hand agreed on) remove to some other object before-hand agreed on, suppose to H; and then to proceed as before.

Lastly, if the sand runs so far out to sea, that the object cannot be seen by the boat, nor the boat by the observer on shore, there may be rockets fired by the boat's crew, and also by the observers on shore in the night, whereby those bearings may be taken almost at as great a distance as the light can be seen. For supposing they rise but a quarter of a mile above the apparent horizon, its stay will be about 9 seconds, and its distance for this quarter of a mile will be visible about 44 miles.

But rockets rise much higher, and then the distances are much greater, whereby they are visible.

Or two boats may lay at anchor instead of the land-marks, and then you may work as before.

Now

Now, since the land-marks B and C are fixed, their position may be laid down in the draught, as in common surveying, by plotting the distance between B and C. And then, by plotting the line BD, and the line DC, according to their position, their common intersection will give the point D. And in like manner E, F, G, &c. may be plotted; and so the shoal: And this from the bearings taken at B and C.

If this be a standing lake, environed by bogs, not to be walked on, the observations at D, E, F, &c. by taking their opposites, may suffice to plot the same from the land-marks A, B, C, &c. as well as those taken on the land; or, indeed, by the course and distance, as in navigation, if the water be smooth and without a current.

In sea-shoals, it is convenient to note at each observation the depth of the water found by the lead, and the drift and setting of the current by the log and compass, while the boat is at an anchor, which may be done with ease and expedition enough. For while the boat rides at an anchor, her stern points out the setting of the current, and the log and glass will measure its drift.

And these ought to be noted on the draught, which may be thus:

The currents may be shewn, by drawing a dart pointing out its setting, and its drift by the Roman capital letters, and the depth of water by the small figures.

All nocturnal observations ought to be several times repeated.



S E C T.



S E C T. X.

Of Water-Levelling, or the conducting of Water.

THE first thing necessary to this purpose, is the adjusting of the level, which may be performed several ways: This that follows is very easy and natural.

Chuse some ground which is not above 4 or 5 feet out of the level, for the distance of 8 or 10 chains length, and suppose it to be AB (fig. 31.) and find the middle between A and B, which suppose to be C; plant the instrument at C; direct the tube to a station-staff, held up at A, and elevate or depress the tube, till the bubble is exactly in the middle of the divisions; then by signals direct your assistant at A, to raise or depress the vane, sliding on the station-staff, till the horizontal hair in the glass, cuts the middle of that vane; then see how many feet, inches, and parts, are cut by the upper part of the vane, which suppose to be 3 feet 4 inches, and 6 tenths.

In like manner direct to the other staff at B, and suppose the upper edge of that vane to cut at the height of 6 feet 5 inches and two tenths; then will these two vanes be on a level.

From 6 feet 5. 2 inches subtract 3 feet 4. 6 inches, and reserve the remainder 3 feet 0. 6 inches.

Now, remove the instrument as close to the higher station-staff as you can; so that the middle of the telescope may almost touch it. Then bring the telescope as near to a level as the judgment of the eye will direct,

Measure

Measure from the ground, the height of the top of the telescope; and also of the bottom, in feet, inches, and parts: Suppose them to be 4 feet 10. 5 inches, and 5 feet 0. 3 inches; then half the sum of these heights 4 feet 11. 4 inches is the height of the center of the glass; and to this add half the breadth of the vane, which suppose to be 1 inch and 5 tenths, and to the sum 5 feet 0. 9 inches; add the preceding remainder 3 feet 0. 6 inches; then let the person at B move his vane, till the upper edge cut 8 feet 1. 5 inches, the sum of the preceding numbers.

Now, so elevate or depress the hair or the bubble, till the hair cut the middle of the vane at B, and at the same time the bubble stands in the middle of the divisions; and then will the instrument be duly adjusted.

If you have a mind to be curious, repeat the operation; but when you place the instrument at C, turn the tube at right angles to the line AB, and there set it level; then proceed with the repetition of the work. Only observe to cross-level it in this adjustment, and in all future uses whatsoever.

Or the level may be adjusted thus: As before, first plant the instrument in the middle between A and B (fig. 32.) and observe the heights on the station-staves, which suppose to be as above; and consequently their difference, as before, is 3 feet 0. 6 inches. Now measure from C towards the highest ground A, some distance that comes almost to A; suppose 4 chains to D, and DB will be 9 chains, and DA one chain: Then plant the instrument at D, direct the telescope to A, and, setting the bubble to the middle of the division, direct your assistant to move the vane, till the hair cuts the middle of it; and note down the feet, inches, and parts cut by the upper edge of the vane; which suppose to be 3 feet 8. 4 inches: To this add the difference

rence 3 feet 0. 6 inches, and the sum 6 feet 9 inches reserve.

Now direct the telescope to the staff at B, level it, and direct your assistant to move the vane, till the hair cuts the middle thereof; and then, if the upper edge of the vane cuts the foregoing sum 6 feet 9 inches, the hair and bubble are truly adjusted. But if not, say, As BD wanting AD, is to the difference between the numbers cut by the upper edge of the vane, and the number 6 feet 9 inches; so is the distance AD to a number, which added to that cut by the vane, when less than 6 feet 9, and subtracted from the number cut by the vane, when it is greater than 6 feet 9, will give a number, to which let the assistant fix the vane; then so elevate or depress the hair or the bubble, till the hair cuts the middle of the vane at B, and the bubble stands in the middle of the divisions; for then the level will be adjusted. The operation may be again repeated, and at every station cross-levelled, which will confirm the former adjustment.

After the instrument is duly adjusted, you may proceed to use it. Let the example be this annexed, (fig. 33.) where A every where represents the level, and B the station-staves; and suppose the rout be made from a to e; first plant the instrument between the station-staves a and b: at A direct the level to a B, bring the bubble to the middle of the divisions, and instruct your assistant so to place the vane, that the hair in the telescope cuts the middle of the vane; then in a book divided into two columns, the one intituled Back Sights, the other Fore Sights, enter the feet, inches, and parts cut by the upper edge of the vane at aB, in the column intituled Back Sights.

Then look towards the other staff b B, bring the bubble to the middle of the divisions, and direct your assistant to place the vane so, that the hair cuts the middle of the vane; then enter the feet, inches, and parts

parts cut by the upper edge of the vane, in the column of Fore Sights.

Now, plant the instrument at A₃, still keeping the staff Bb exactly in the same place, and carry the staff a B forwards to the place c B; now look back to the staff b B, and enter the numbers cut by the vane there, under the title Back Sights; then look forwards to c B, and enter the observation under the title Fore Sights. Do the like when the instrument is planted at A₃, A₄, &c. always taking care to keep the staff in the same place when you looked at it for a Fore Sight, till you have also taken with it a Back Sight.

Having finished your level, add up the column of Back Sights into one sum, and the column of Fore Sights also into one sum, and the difference between these sums is the ascent or descent required. And if the sum of the Fore Sights is greater than the sum of the Back Sights, then e is lower than a; but if the sum of the Fore Sights is less than the sum of the Back Sights, e is higher than a. For example-sake, let the numbers be as in the following table:

Back Sights.			Fore Sights.		
Feet.	Inch.	Tenths.	Feet.	Inch.	Tenths.
3	• 7	, 5	6	• 4	, 5
4	• 6	, 8	8	• 3	, 2
6	• 0	, 2	5	• 4	, 7
9	• 5	, 0	8	• 7	, 8
1	• 0	, 7	9	• 4	, 8
24	• 8	, 2	38	• 1	, 0
			24	• 8	, 2
			13	• 4	, 8

Hence the descent is 13 • 4 , 8

Now

Now follow some observations well worth notice:

I. If the sum of the distances in taking the Back Sights, is equal to the sum of the distances in taking the Fore Sights, all the minute errors of the instrument will mutually balance and destroy each other.

II. And if the distances thus taken are short, the curvature of the earth may be rejected. For, if the distance from the instrument be every where about 100 yards, all the curvatures in a mile's work will be less than half an inch.

III. If the distances from the instrument to the hindermost staff, be every where equal to the distance from the instrument to the corresponding staff, the curvature of the earth, and the minute errors of the instrument will both be destroyed.

IV. If the distances of the instrument from the staves, be very unequal and very long, the curvatures must be accounted for, and the distances, in order thereto, must be measured, either by pacing, by a chain, or a wheel.

V. For the more ready allowing for the curvature, you may observe, that the curvature for one mile, taken at one observation, is extremely near to 8 inches. And at all other distances, it is as the square of 1 mile is to 8 inches, so is the square of any other distance to the allowance for the curvature; that is, Multiply the square of any distance whose measure is taken in miles, by 8, and the product will give the allowance for the earth's curvature in inches: This curvature is always to be subtracted from the numbers taken off the station-staff. Or if the distance be less than a mile, and taken by the four pole

pole-chain: Square the chains, cut off 2 places to the right-hand, and divide those to the left by 8, and the quotient shews the inches and parts of inches to be allowed for the curvature. Suppose the distance be 30 chains; then the square of 30, that is, 900, when 2 places are cut off, gives 9,00 or 9, which divided by 8, gives one inch and 125 thousandth parts of an inch.

VI. If these distances were taken by pacing, accounting 25 to the chain, the curvature may be found thus; Square the paces, and double it, cut off 6 places to the left-hand, and those to the right are the inches of curvature: So, if the paces were 900, then from 810000 multiplied by 2, that is, 1620000, cut off 6 figures, and you have 1.62, the curvature to be allowed. To save the trouble of continual calculations you may use the following table, wherein the distances are in chains, and the allowance in inches, and 100th parts of an inch.



Distan.	Allowance	Distan.	Allowance
Chain	Inches	Chain	Inches
1	0,00125	27	0,91
2	0,005	28	0,98
3	0,01125	29	1,05
4	0,02	30	1,12
5	0,03	31	1,19
6	0,04	32	1,27
7	0,06	33	1,35
8	0,08	34	1,44
9	0,10	35	1,53
10	0,12	36	1,62
11	0,15	37	1,71
12	0,18	38	1,80
13	0,21	39	1,91
14	0,24	40	2,00
15	0,28	45	2,28
16	0,32	50	3,12
17	0,36	55	3,78
18	0,40	60	4,50
19	0,45	65	5,31
20	0,50	70	6,12
21	0,55	75	7,03
22	0,60	80	8,00
23	0,67	85	9,03
24	0,72	90	10, 12
25	0,78	95	11, 28
26	0,84	100	12, 50

VII. Therefore it appears, that the best method to take a level, is to measure the several distances from the instrument to the back and forward station staffs; and enter them in the field-book, according

to the titles of their several columns, as in the following example; and correct the heights from the table of allowances; which may be done at home, when you are about to sum up the heights.

Lastly, Though hitherto we have considered the level with one telescope only, the same observations may be applied to a level with a double telescope; and I would advise those who use the double telescope, at every station to turn that end of the telescope towards the spring, which before was the contrary way.

Backwards.			Forwards.		
Distan.	Height.	Corrections.	Distan.	Height.	Corrections.
Links.	Inches.	Inches.	Links.	Inches.	Inches.
370	3,25	3,24	418	4,36	4,34
430	6,10	6,08	328	7,18	7,17
760	5,38	5,31	289	6,75	6,67
584	7,25	7,21	530	9,53	9,50
326	8,15	8,14	485	11,25	11,22
658	10,25	10,20	376	8,65	8,63
530	6,32	6,29	720	10,34	10,28
3658		46,47	3146		57,81
3146					46,47
68,04					11,34

So that the fall in 68 chains is about 11 inches and one-third of an inch.

K SECT.



SECT. XI.

Of COLOURS.

IT is not worth while to speak of the preparation of colours, because they may be had ready prepared, at almost every colour-shop and fan-painter's, &c. Nor to mention but as many as are necessary and most fit for the surveyor. I judge those to be the best, which are most transparent.

And for portability, I think liquids improper; therefore would rather chuse those colours, which, before tempered, are dry; whether in powder, or in lumps: And such as require no other liquid to mix with them (than what is to be had every where) *viz.* fair water.

For Gum Water, with which many colours are mixed, is made by barely steeping Gum Arabick in fair water.

Carmine, a powder, mixed with Gum Water, is a beautiful red; may be shaded with some of the same, mix'd stronger; or with any reddish brown, or any sadder red.

Carmine is chiefly used for drawing of red lines to represent the walls of gardens or other places; and also to colour the plans of buildings.

Ultramarine, a powder, mixed with Gum Water, is a most valuable blue, fit to shew ponds, lakes, rivers,

rivers, &c. it may be shaded with Indigo Corns ground with fair water on a white tyle, by the pressure of a knife's point, and then mix'd with Gum Water.

Red chalk, a lump, sometimes called French Chalk, ground by rubbing it on a tyle with fair water, and afterwards with Gum Water, slightly laid on, is proper to represent roads and pits; and is shaded by itself more strongly mixed.

Sap green, steep'd in water, is of itself a good green to colour trees.

Verdigreece, in lumps, dissolved in vinegar, or in water, makes a greenish blue, or sea-colour, very transparent.

Gumbooge, in lumps, steep'd in fair water, produces a beautiful and transparent yellow.

Yellow berries, steep'd in fair water, a yellow.

Verdigreece dissolved, mixed with Gumbooge, or yellow berries, in different proportions, produces different greens, inclining either to the blue or yellow, according to the quantities of either used.

Indian Ink is used in drawing the first lines of a draught, and in shading of hills and descending grounds: A proper quantity of it may be liquified when wanted, by putting a few drops of water on a cake, and rubbing it with the finger until the colour is as deep as desired.

But there must be care taken in the using of Indian ink, *viz.* to have three or four different tints of colour prepared, of which the faintest is to be

laid on first, and so proceed to the deepest tint; also not to cover too great a space at once; for if the margins are not speedily washed off, the ink will dry in streaks and spots, and look very ill.

Colours are laid on with hair-pencils; those fit for most uses, are about the size of a common writing quill, and the length of the hair, without the quill, not to exceed six or seven tenths of an inch: In chusing them take such only as, when wetted either in your mouth, or in water, will, by stroking them across your finger, form a fine point, and are very springy: And as most pencils have a hair or two at their point longer than the rest, these may be taken off, by gently drawing the point, when the hair is wet, once through the border of the flame of a candle.

In the using of these pencils, it will be found convenient to have them fixed on small sticks about six inches long, one on each end; whereof one is to be used with colour, and the other with fair water, to lighten the margin of the colour, whereby it is insensibly graduated till it vanishes into the colour of the paper.

All colours are shaded by others of the same sort, but of a stronger tint: and the manner in which they are used with the most facility and success, is better gained by practice than by precepts,

SECT.



S E C T. XII.

A farther use of the Theodolite (as now improved;) conjointly with the use of a Sliding-Rule aptly divided; to measure timber, either round, or hewn to a square, or unequally squared. Also how to allow for ascents or descents by finding the horizontal lines.

THE principal difficulty in using this Sliding-Rule, is, in justly distinguishing the value of each division. And in order to this, it may be observed, that the divisions on this rule, may be distinguished into three orders, &c. the longest, the mean, the shortest. And these different marks distinguish the value in a ten-fold proportion, in the same manner as the places of a number is distinguished.

So that, if the longest represent hundreds, the mean will represent tens, and the shortest units.

And if the longest represent tens, the mean will represent units, and the shortest tenth parts.

Also, if the longest represent thousands, the mean will represent hundreds, and the shortest tens; and in this case, the units must be estimated by the eye, in judging at divisions, only supposed to be drawn, because there is not room enough.

The longest divisions are generally numbered by the figures 1, 2, 3, 4, 5, &c. and when they are numbered thus, 1, 2, 3, 4, 5, 6, 7, 8, 9; 1, 2, 3, 4, 5, 6, 7, 8, 9, 1; the line is called a double one. And when the longer divisions are in number only

ten, and numbered 1, 2, 3, 4, 5, 6, 7, 8, 9, 1; or numbered 5, 6, 7, 8, 9, 10, 20, 30, 40, 50; or broken, so as to begin at any other number, so as to contain only ten long divisions; the line is called a single one; and these are called Gunter's lines, from the name of their author.

But we may observe, that although these divisions represent equal distances, yet, from their use, they cannot be so. Nor will they be easily capable of an equal number of divisions, in different parts of the rules; either of mean, between the longest, or of the shortest between the mean.

But in order to make this easy, here follows an explanation of the divisions laid down on the Foot Sliding-Rule, which may easily be applied to other rules of greater length, where the multitude of the intermediate divisions may be greater.

On the slider are two of these double lines, both alike; one of which moves against the fixed line above, which is exactly like to either of the other; and the undermost line on the slider moves against a single line, beginning with the numbers 5, 6, &c. and going on to 50.

If the first 1 be called an unit, the following numbered divisions, till you arrive at the middle 1, will be units; and the mean divisions will be tenth parts.

If the first 1 be called ten, the figures 2, 3, 4, &c. immediately following it, will denote 20, 30, 40, &c. And the mean divisions, that is, the next longest in order, will denote units; the fifth of which is, for distinction, made longer than the rest: And from 10 to 20, between each of these mean divisions, the shortest denote each two tenth parts, because the distances between the mean divisions, are divided into five parts; but if the distances between these mean divisions were divided by shorter lines into ten parts,

parts, which is seldom done on rules so short, each would represent one tenth part.

In like manner from 20 to 30, that is, between the divisions marked 2 and 3, the same order follows; save that the distances between the mean divisions (because of their nearness to one another) are divided into two parts only; and consequently each of these shortest divisions will denote five tenth parts; and the eye must estimate the other tenths not cut, but supposed to be cut between them: tho' in larger instruments, even here, and elsewhere, the shortest divisions may be as many as those between the 10 and 20.

This last multitude of divisions, usually continues to 40, 50, or perhaps farther, and are to be read as those between 20 and 30.

But where the longest divisions become closer together, as generally they do, between 80 and 90, and between 90 and 100, which, on the scale, is denoted by the digits 8, 9, 1, there are but two orders of sub-divisions; the greatest still keeping the same degree, and the other the next lower degree. And in this one example, the figured divisions denote tens, and the other units.

But when the first 1 is called 100, then the figured divisions will be accordingly 200, 300, 400, &c. The mean divisions, or those the next shortest, will denote tens. The shortest between 100 and 200, where the distance between the tens is divided only into five parts; I say, the shortest here will denote two units each of them; and the middle between these, will denote the single units; which, if there had been divisions, as in large instruments, would have been denoted by those divisions.

But from 200 to 300, from 300 to 400, and from 400 to 500, the distances of the divisions representing tens, are divided only into two parts, and consequently, each of these shortest divisions must re-

present five units; and all other units, either more or less than five, must be estimated by the eye, by supposing each of these distances cut into five parts. Nevertheless, in larger instruments, these divisions may be cut and estimated as before shewn.

Towards the latter end of the line, the divisions on these short lines are so near together, that they scarce admit of three orders of divisions, and consequently (supposing the longer divisions to denote hundreds, as in this example) the units must be estimated by the eye.

And in like manner, if the longer or figured divisions denote thousands, the lines of lesser length will denote hundreds, the next inferior tens, &c.

But because, by inspection, on this rule it will appear, that more than three places cannot be distinctly estimated; and, that those are sufficiently exact for all the uses it is designed for, a farther division, and consideration thereon, are omitted.

If the first 1, that is, the beginning of the first line, denotes a unit, then the middle 1, or beginning of the second line, denotes 10, and the last 1 denotes 100.

So, if the first 1 denotes 10, the second 1 denotes 100, and the last 1000.

In like manner, if the first 1 denotes 100, the second denotes 1000, and the last 10,000.

And since, when the value of the first 1 of any line is known, the value of the other figures and divisions are known also; therefore the latter line is to be read by the former directions. And thus are these three double lines to be read, as has been shewn for the former.

But the single broken line, which is on the fixed part of the leg of the rule, is not to be considered in this arbitrary manner.

For the longer divisions have affixed to them their values, which ought to be considered as unvariable, unless

unless in some particular necessities hereafter to be taken notice of.

From the beginning of this line, to the division marked 10, the distances of the longer divisions, which are numbered 5, 6, 7, 8, 9, 10, are divided into 10 parts, by mean divisions; and therefore, these mean divisions denote tenth parts. And these mean divisions are each subdivided by one short line, each denoting therefore half of one tenth.

From 10 to the end of the rule, the distances between the longer divisions are each divided into 10 parts, and therefore each denotes units. And the distances between the units are each divided into 4 parts; therefore each denotes one fourth part of an unit.

In the double lines, let the distance between the 1 at the beginning, and the 1 in the middle, be called the first scale; and the distance between that in the middle, and the 10 at the end, be called the second scale. The uppermost of these double lines is marked with the letter A, the next with B, the third with C, and the undermost, which is also called the girth-line, with D.

On the lines A and B, in the second scale, there are placed the small figures 12, denoting an index fixed, tho' the value of the divisions should vary.

And, on the girth-line, against 12, is generally a hand or index for the like use.

The two upper lines are generally used for casting up the surfaces of planks.

The two under ones for finding the solidity of timber.

Having thus far described and explained the reading of this rule, I shall proceed to shew its use in measuring planks and timber. But shall first shew the customs used in taking their dimensions.

And

And first for planks; the buyer hath the liberty of measuring the dimensions on that side of the plank he judges most advantageous to himself.

Then the length is measured either with two two-foot rules, or two-foot rules, and five or ten-foot rods.

The length is measured in feet and half feet, and in some places, to quarters of feet.

Then lay half this length from the upper part, down towards the butt-end, where, with a piece of chalk, make a mark.

At that mark, or nearer the butt-end, if the buyer think it to his advantage, is taken the breadth, in inches and half inches.

If one side be wainy, the breadth is taken to the middle of the wain.

If both sides are wainy, one wain is measured, the other rejected; and either of them as the buyer thinks fit.

Having thus got the length and breadth, call the first long division on A, and also on B, each an unit. Then set the index on B, against the breadth in inches on A, and against the length in feet on B, will stand the content in feet on A.

E X A M P L E.

Let there be a plank, whose length is 24 feet and a half, and breadth 17 inches and a half; I demand the content.

Set the index (or 12, in the second scale) on B, against 17 inches and a half on A, and then against 24 feet and a half on B, stands 35 and 3-4ths nearly on A; which is the measure of the plank required.

But when the feet, in length, on B falls beyond the end of the line A, then call the first 1 on A, a ten, and work as before shewn.

E X-

EXAMPLE.

If a plank be 45 feet and a half long, and 39 inches broad, what is the content?

Set the index (or 12) on B, against 39 on A, and 45 and a half on B, will fall beyond the upper end of A.

Therefore set the index on B, against 39 on A, taking in the first scale of A, because the 1 on A is counted 10; and then, against 45 and a half on B, will stand 148 on A, the content required.

These are all the varieties which happen in plank measure.

But notice may be taken, that from this content must be subtracted as much measure as will ballance all the visible faults: and this is generally left to the judgment of the two measurers, and generally done before the contents are entered in the accounts, or indeed, before you pass to another plank.

There are some differences in the customs of different countries, though, for the most part, the foregoing are the most generally used.

The customs generally used in taking the dimensions of timber, are not much different from those used for plank.

For the whole length is first taken in feet and halves, then the middle is found and chalked, where, or nearer the butt-end, according as it is the buyer's advantage, the stick is girthed with a small line, which is exactly quartered by twice folding; this quarter is measured in inches, halves, and quarters. And if the tree's bark is not peeled, as always happens in standing timber, then from the foregoing girth must be made an allowance for the bark, which

is

is usually thus: for trees girthing one foot, allow one inch, and so proportionally for all others. But for beech, elm, ash, and such as are thin barked, the allowance must be a small matter less.

It is also to be observed, that a stick is not called timber farther than it will hold half a foot girth. Also, that if there be any considerable arms which hold half a foot girth, they are also called timber, and measured as such.

CASE I.

Having thus taken the length in feet, &c. and quarter girths in inches, &c. set 12 (the index) on the girth line, to the length on C, and then against the girth on the girth line, is the solid content on C.

EXAMPLE I.

Let a tree be 24 foot and a half long, and its quarter girth 17 inches and one fourth; to find the solid content:

Sett 24 and a half on C, against the index on D, the girth line; and then against 17 and one fourth on the girth line, stands 50 three fourths on C, the solid content of the stick.

CASE II.

When, by the foregoing directions, the rule is set, and the girth on the girth line is beyond the upper end of C, call the first 1 on C 10, and then work as before.

EX-

EXAMPLE II.

Let a tree be 30 inches girth, and 40 feet and a half long; to find the solidity:

If you set 40 and a half on C, against the index on D, then 30 on D is beyond the upper end of C.

Therefore, calling the first 1 on C 10, set 40 and a half on C, to the index on the girth line D; and then against 30 on D, will stand 253 on C, the solidity required.

C A S E III.

When the girths on D fall short of the lower end of C; call the middle one on C, a unit; and then, all the figured divisions, below the middle 1, will be tenth parts of feet; then work as above.

EXAMPLE III.

Let a stick be 3 feet long, and 6 inches girth; to find the solid content:

Accounting the middle 1 on C an unit, set 3 on C against the index on D; and then, against 6 on D, stand 7 tenths and a half on C; the solidity required.

EXAMPLE IV.

Let a stick be seven feet and a half long, and girth four inches; to find the solidity:

Set the index (12) on D against 7 and a half in the second scale on E; then against 4 on D stand 8 tenths

8 tenths and a third on C: so that the solidity is 8 1-third part in 10 of one foot.

N.B. Tho' this is not what is called timber, yet since alders and other shrubs, used by turners and others, are often measured, be they never so small, I thought it proper to insert some examples of this kind.

In the three foregoing cases, the girths of the sticks fell on the girth line C, without any arbitrary alteration of the values affixed to the divisions; which fixed values are abundantly sufficient for computing the solidity of most sticks usually to be met with, if the single line C be advantageously broken. For, if a person designs his rule for the measure of timber only, that is, such as never girths less than six inches, then the girth line beginning at six, will run to sixty inches; above which, few sticks will out-run. But if he designs to measure alders, shrubs, and small things, &c, often measured by turners, wheelwrights, and other artificers, using this small stuff, the best way is to have the line C broke, and to begin at 1 and a half, or 2, and end at 15 or 20, according to the size of the stuff they most deal in.

But that the line, as usual, or occasionally broken, may serve for the computing of common timber, timber extraordinary large, out-running the girth line, and also for shrubs and small twigs, it may not be amiss to consider the following directions and examples.

And in the first place, we will enquire into the use of the rule in computing the solidity of such large sticks, as out-run the affixed values of the divisions on the girth-line.

For which observe, that the length of a stick always to be found on the upper end of the line C, is to be set to the index; the divisions on the girth
line

line numbered 6, 7, 8, &c. are to be accounted 60, 70, 80, &c. and that, in estimating the solidity of the stick, the divisions on C are to be estimated by 100 times the value arbitrarily taken thereon by the length; that is, if the second scale of C be called units in the length, then, in the solidity, the same upper parts shall be called hundreds, and the lower scales tens: in like manner, if the upper part of C be called tens in the length, then, in the solidity, the upper part shall be called thousands, and the lower part hundreds.

EXAMPLE V.

Let there be a stick, whose length is twenty-five feet, and girth forty-six inches; and let forty-six be above the upper end of the girth-line, to find the solidity.

Then set twenty-five in the second scale of C, against the index on D; and then against (4 and 6 tenths on D, which in this case represents) 46 inches the girth, stands 367 feet on the first scale of C, estimated according to the preceding directions.

EXAMPLE VI.

Let there be a stick, whose length is four feet, and girth forty-six inches; and let forty-six be above the upper end of the girth-line, to find the solidity.

Set four in the second scale of C, against the index on D; and then against the girth 46, on the lower part of D (which, in this case, will be represented by the affixed value, four and six tenths), stands 59 fere' on the lower part of C, estimated according to the preceding directions.

For

For very small sticks, whose girth falls below the beginning of the girth line D, observe that the length of the stick always to be found on the first scale of the line C, is to be set to the index; the divisions on the girth line numbered 10, 20, 30, &c. are to be accounted only 1, 2, 3, &c. And that estimating the solidity of the stick, the divisions on C are to be estimated by the 100th part of the value arbitrarily taken thereon by the length; that is, if the first scale of C be called units in the length, then in the solidity, the same lower part shall be called hundredth parts only, and the upper end tenth parts. But if the lower end of C be called tens in the length, then, in the solidity, shall the same lower part be called tenth parts, and the upper end units.

EXAMPLE VII.

Let a stick be fifteen feet long, and let its girth be three inches; and let three be below the lower part of the girth-line, to find the solidity.

Set fifteen feet, taken in the first scale of C, to the index on D; and then against three (which, in this case, will be represented by thirty) in the upper part of D, stands the solidity nine tenths of a foot, and a quarter of another tenth.

EXAMPLE VIII.

Let a stick be three feet long, and let its girth be two inches; and let two be below the lower part of the girth-line, to find the solidity.

Set three feet, taken in the first scale or lower end of C, to the index on D; and then against two (which in this case will be represented by 20) in the upper part

part of D, stands the solidity, eight hundredth parts of a solid foot, and something more.

In those places where the custom allows the taking the length to minute parts of a foot; or when the length is less than one foot, take the dimensions in feet, and decimal parts of feet.

Thus much for round timber; but when timber is hewn to that form which is usually called square, tho' at the same time there is most commonly four waness, the custom is to take the length, and find the middle in the same manner, and with the same allowances as were observed in round timber; and then, in this middle, either with a pair of callipers, or the edges of two rules applied to the flat faces, to take the breadth and depth of the stick. Then, to add the breadth and depth together, and to use half their sum, as you before did the quarter girth of a round stick.

E X A M P L E.

Let a stick be twenty-five feet long, fourteen inches broad, and twelve deep: to find the solidity according to this customary method.

Because 14 and 12 give 26, whose half is 13, set 25 on C against the index on D; and then against 13 on D, stands almost 29 feet and a half solid.

And tho' this custom makes the stick something more than in fact it is, by adding the breadth and depth together, and taking their half for a girth; yet, in a whole tree, only hewn to a square, the difference is so very small, that the custom may be admitted.

For in this example it may appear by the pen, that the solidity thus is $29\frac{49}{144}$ feet; and the true solidity, if the stick be all of the same bigness, and

L

without

without wanes, will be $29 \frac{24}{144}$, differing from the former only $\frac{35}{144}$, or $\frac{1}{8}$ of a foot solid.

Nevertheless, in sticks whose breadth differs very much from the depth, the error is intolerable, and ought not to be admitted.

For, let there be a stick 25 feet long, 20 inches broad, and 6 inches deep; then, by the customary way of adding the width and depth together, the solidity will, as before, be $29 \frac{49}{144}$ feet; but the true solidity will be only $20 \frac{120}{144}$: and so the error is $8 \frac{73}{144}$ feet, almost a third part of the stick.

For the ready management of such timbers, there may be placed on the other leg of the rule, another slider; having the sliding part and the upper fixed line, exactly the same as in the former leg; but on the other fixed part, a double line of the same radius with the former, but broken and inverted. And as the lines on the former leg were distinguished by the letters A, B, C, D, so the lines on the latter are noted by the letters E, F, G, H. And as the divisions on the lines A, B, C, were intirely arbitrary, so the lines E, F, G, are also intirely arbitrary. And on the line H, which is inverted, and beginning at 1 and a half, and running on to 150, the values annexed to the divisions, may be varied, or remain unvaried. But on the line E being direct, beginning at 1, and running on to 100, the values annexed to the divisions, may be constant.

The line H, I call the depth line; the line G the breadth line; the line E, I call the length line, and F the content line.

The use is so short and so easy, that, in a few words, and two or three examples, it will be plain.

For, set the breadth on G, against the depth on H, and then the length on E will stand against the solid content on F.

Let

Let the stick be that of the last example, where the length was 25 feet, breadth 20 inches, and depth 6 inches.

Set the breadth 20 on G, against 6 on H; and then, against 25 on E, will stand on F almost 21, the solidity required.

And, to avoid confusion, remember, that whatsoever is the value of the divisions on G, the same shall be the value of the divisions on F. That is, if the former division on G be units, and the latter tens, then the former division on F shall be units, and the latter tens. And if the former divisions on G be tens, and so the latter hundreds; then the former on F shall be tens, and the latter hundreds.

If the length on E falls beyond F, call the former divisions on F, tens, and the latter hundreds.

If the length on D falls short of F, call the former divisions on E tenth parts, and the latter units.

E X A M P L E.

Let a stick hewn to unequal square sides, have its length 46 feet, its breadth 30 inches, and its depth 20 inches; then, when 30 on G is set against 20 on H, 46 on E will fall beyond the line F; therefore call the former division on F, tens; and then set as before, and against 46 on E, will stand 191 1-third on F, which is the solid content.

The shell, or flitch of timber, is readily cast up by this rule; for, take the breadth on the flat side in the middle, and one half the depth in the middle, and work with the length and these, as tho' it were a square stick, and you have the solidity sufficiently near.

It is indeed true, that this is less than the true solidity; but in regard of its value it is thought enough.

Let there be a fitch, whose length is 30 feet, breadth 16 inches, and depth taken in the middle 4 inches. Set 16 upon G to 2 upon H, and against 30 on E, stands on F 6 feet and two thirds, the solidity required.

The sawyers measure is done by one setting of this rule.

For set the number of kerfs or cuts on G, to the breadth of the boards on H, and against the length of the stick on E, stands on F the hundreds of feet superficial.

E X A M P L E.

Let a stick, whose length is 30 feet, breadth 22 inches, and depth 20 inches, be so cut, that each board, with the waste of the saw, may be 2 inches; that is, if it be cut parallel to the breadth, we shall have ten boards, and so 9 cuts or kerfs, and the breadth of each board will be 22 inches.

Set 9 on G against 22 on H, and then against 30 on E, stands 4. 12 on F, that is, 4 hundred and 12 hundredth parts of 120, or another hundred.

Any plank or board, whose value is expressed in pence *per* feet, may be cast up by this rule at one flip, without knowing the measure of it.

E X A M P L E.

A plank of walnut-tree is sold at 2s. 9d. or 33 pence *per* feet, its length is 30 feet, its breadth 26 inches and a half.

Set the price in pence, 33 on G, against 26 and a half on H, and then against 30 on E, stands 182 on F, and a little more; that is, 182 shillings, or 9 pounds and 2 shillings.

It may be observed, that this sliding rule is sufficiently exact, and very ready for cubing stone; provided, that the two shorter dimensions are taken in inches, and the longer in feet, and decimal parts of feet.

Also, that it may be applied to the cubing in feet, any solid in form of a parallelipedon, whose content doth not consist of more than 3 places.

And if a line be properly broken, and put on instead of H, it might be applied to digging, &c.

Or if the line H did slide as well as G, it might be applied to the measuring of all sorts of parallelipedons, by one setting of the rule, whether the answer be required in feet, or yards, or rods, &c.

It remains to say something concerning the estimation of the measure of timber standing.

And, first, we may observe, that, if we can get the dimensions, the manner of computing, after an allowance for bark, is that already laid down.

But since we cannot always get all the dimensions, we must take those we can get at, and estimate the rest.

And first, we may observe, that the dimensions in a tapering stick, which runs beyond timber, may be had thus: Girth the stick breast-high; to an 8th part of this girth add three inches; and the sum lessened by allowance for bark, will give the girth in the middle. And for the length, measure from the ground so high as the tree runs timber, and then work as before.

E X A M P L E.

Let the girth breast high, be 6 feet, and length 40 feet; then, because the 8th part of 6 feet is 9 inches, to this add 3 inches, and the sum is 12;

L 3

from

from this deduct an inch for bark, and there will be left 11 inches; which, with the length 40 feet, gives 33 feet and a half for the solid content.

When the taper stick does not out-run timber at the top, the whole girth, at top, shall be added to the whole girth breast-high; and an 8th part of this sum shall be the girth in the middle; which, after an allowance for bark, shall be the girth to be used.

The usual way of estimating the height of the tree, is, by applying to it a ten or twenty foot rod, and standing at a convenient distance, and comparing the rod with the tree.

But the most certain method is by the Theodolite, as now improved, thus: Measure from the tree with a ten-foot rod, 100 feet, level the Theodolite, and direct the telescope to the top of the tree; and then shall the telescope cut on the vertical arch (if the ground, from the tree to the instrument, be nearly upon a level) a certain number of feet; to which, if you add the height of the telescope, you will have the height of the tree.

But if the ground, from the tree to the instrument, be not quite level, then direct the telescope to the top of the tree, and note the feet cut by the telescope; and then direct the telescope to the bottom of the tree, and note the feet there cut.

And if one of these numbers of feet be above the level, and the other below, then their sum is the height of the tree; but if both are above, or both below, then the lesser taken from the greater, will give the height of the tree, without any other calculation.

When the ground, from the tree to the instrument, is very steep, take, with your off-set staff, or five-foot rod, the height of the instrument above the ground, and at the same height on the tree above the ground the tree stands on, make a mark. Direct the telescope to this mark, and it will cut on
the

the vertical arch among the divisions of reduction, shewing the difference between the hypotenuse and base, a number of feet which added to 100, will give the proper distance to plant the instrument from the tree; or, what is the same thing, it shall give a length on the ascent, answering to 100 feet measured horizontally, very near.

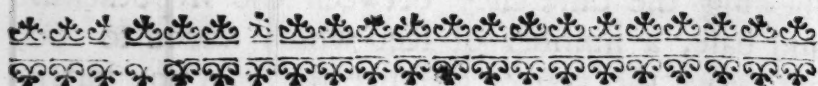
The instrument being planted at this distance, work as before, and you will have the height of the tree correct.

Having mentioned this vertical arch, and its use in taking heights, I will now proceed to shew its farther uses in surveying land.

If, in coming up an ascent, or going down a descent, as soon as the instrument is set for observing the angle, you look on the vertical arch among the divisions of reduction, you will find how many links, in every chain's length; this hypotenusal line is to be shortened, in order to get the horizontal line, which ought to be laid down in your plan, and must be entered in your book.

And these divisions of reduction are concentric with the divisions of altitude and depression, and also with the divisions of degrees.

Lastly, if the distance from the tree to the instrument be confined, then multiply the horizontal distance in feet, by the feet given by the instrument, and from the product, towards the right hand, cut off two figures, and those to the left, will be the height of the tree in feet.



SECT. XIII.

The use of the Theodolite, in drawing the perspective appearance of any building without measuring one single line.

THIS will admit of some variety; for either the picture is supposed to be parallel to one of the fronts of the module or building, or else oblique to both; and then is either in a position assigned, or in a position taken at pleasure.

First, Suppose the picture parallel to one of the fronts; then plant the instrument and a staff at any equal distances from the front, suppose 5, 10, or 15 feet; and direct the telescope to the staff, and the needle will point out the bearing of that front: to this add or subtract 90 degrees, you will have the directing number; that is, the bearing of the line perpendicular to the front.

Now plant your instrument at the place, whence the original building is to be viewed. Bring the index to the beginning of the divisions, and turn the whole instrument about, till the needle points at the directing number, and then screw it fast. Bring the telescope to the beginning divisions in the vertical arch, and level the whole instrument; so will the instrument be duly seated and rectified for observation.

In order to get easily a due knowledge of perspective in general, and particularly of the use of this instrument in drawing, turn to the figures in Plate V. and raise up the draught PK (fig. 1.) perpendicular

pendicular to the plane of the leaf upon the line WK, and lift up the plane AYW (fig. 2.) till it is perpendicular to both the plane of the leaf, and also to the draught PK; then raise the draught ABW (fig. 3.) till it coincides with AYW, and consequently will be perpendicular to the plane of the leaf, and also to the draught PK; so will the two draughts AW, PK, be the two fronts of the module, represented to the eye. Lift up the draught a V (fig. 4.) till it is perpendicular to the plane of the leaf, and it will be the picture designed to be drawn, and will coincide with PK, the front of the module. T is the point on the ground whence the building is to be seen. Lift up E T, till the point E is perpendicular over the point T: And E is the eye of the spectator, or the centre of the telescope. Now if you conceive straight lines drawn from the eye at E, to the several points A, B, C, D, &c. in the module, they will meet the picture in the points a, b, c, d, &c. which are therefore the true appearances of those original points A, B, C, D, and a line drawn from a to b, will be the true appearance of A B; and so of all other lines; for the rays of light come to the eye from the picture in the very self-same direction that they would have come from the original module. Thus much by way of introduction.

Now, in order to draw the picture: Assign on your drawing board any point C, at pleasure, for the centre of the picture, and draw C V the horizontal line, and perpendicular to it, the vertical line CX: from these two lines, all the parts of the building are to be laid down by their apparent distances from them.

N.B. By the centre of the picture, I mean that point, whence a line drawn to the eye is perpendicular

cular to the plane of the picture. The horizontal line is that which passes through the centre, and is parallel to the horizon, and therefore is the common intersection of the picture, with the plane of the ocular horizon.

The principal line in these draughts is, that coin, or that angle which is common to both the picture and the module ; and consequently every where proportional to the building itself, and is the first line to be laid down and divided, which may be done thus: Let the example be as in the preceding scheme :

Direct the telescope to the point P in the building, and you will find the index on the horizontal plate of the instrument cut 32 feet and a half, and on the vertical arch 25 feet ; lay the latter above the horizontal line C V, perpendicular to it, from C to X, and the former from C to x. Then, by help of the square, draw x P, X P perpendicular to CV, CS, whence the perspective appearance of the point P is found.

In like manner may be found the perspective appearance of any point whatsoever, whether it be coincident to both the module and picture or not.

Depress the telescope to W, in the building, and (in this example) it will cut on the vertical arch 9 feet ; which, because you look downwards, lay from x downwards to W in the picture, and so you have the true appearance of W ; and consequently, if you draw PW in the picture, you have the true appearance of the line PW in the building.

If you elevate the telescope to A', in the building, it will cut on the vertical arch 15 feet, which laid from x to A' in the picture upwards, because the point is above the horizontal line CV, will give the representative of that point in the picture. And thus may every one of the points B', C', D', &c. be laid down in the picture. Direct

Direct the telescope to K' in the building, and you will find on the horizontal arch, that the index cuts 69 feet and a half; which laid from C to L' , gives in the picture, the representation of the point L' .

Thro' L' , draw $E' L' K'$ perpendicular to CV , and $A'E'$, $B'F'$, $C'G'$, &c. parallel to it, thro' the points $A'B'C'$, &c. and so the coins $E'K'$, and the tops and bottoms of the doors and windows may be limited in respect of their heights.

Direct the telescope to Q , and it will cut on the horizontal arch 38 feet and a half; which lay from C to Q' , and it will determine the appearance of Q' . In like manner may N' ; and the jaumbs of the windows $Q'N'$, $M'O'$, be laid down. As also the other windows, doors, &c.

For the returned front a W , draw PC , WC , $A'C$, BC , $C'C$, $D'C$, &c. and they will limit the heights of the parapets, facia's, windows, &c.

Direct the telescope to b , d , f , h , &c. and it will cut on the horizontal plate 16 feet, 17 feet and a half, 19 feet and one third, &c. ———, which laid from the vertical line XS , will give the breadths, representing the piers and windows.

The same may be done for the chimneys and their returns; or for any other lines, breaks, &c. And so the several parts of the perspective appearance of a building may be drawn without measuring.

That this compendium of perspective may be compleat, it may not be amiss to lay down the necessary Theorems in the most general manner possible; and herein I shall use those terms which Dr. Brook Taylor hath thought fit to mention, they being more comprehensive than such as are used by the other writers on this subject.

Theor. I. All the lines of any object (as in a module or building) which are parallel to one another,
and

and to the picture ; will be represented by parallels on the picture.

Theor. II. All lines parallel in the module or building, which are perpendicular to the picture, will, if continued, run to the center of the picture. Tho' these parallels be or be not all in the same plane.

Theor. III. All lines in the module or building, perpendicular to the plane of the horizon, will be in the picture, perpendicular to the horizontal line. And these three Theorems are sufficiently visible in the preceding example.

Theor. IV. All lines in the module or building, parallel to one another, and to the plane of the horizon, but oblique to the picture (as in the following example, see Plate VI) will meet in some one point in the horizontal line CV. Thus the parallel lines in the front W a, meet in the point V ; and those of the front PQ, meet in the point Y. These points V and Y are (by Dr. Taylor) called the vanishing points of these parallels, and by him are thus found :

From T, the point representing the place from whence the building is to be viewed, draw a line parallel to those parallel lines in any front or face of the object ; and where it meets the ground-line SR, draw a line RY perpendicular to SR, and its intersection Y with the horizontal line VY, will be the vanishing point required.

Theor. V. All the lines of an object which are parallel to one another, but oblique to the picture, and not parallel to the plane of the horizon, will be represented by lines meeting in a vanishing point, found by the intersection of the picture, and a line drawn

drawn from the eye parallel to those parallel lines. But this vanishing point will not be in the horizontal line, but either above it or below it.

Theo. VI. The shadows of all parallel lines made by the intersection of the Sun's rays, will, on the ground, be parallel; and consequently in the picture, either be parallel, as in Theorem I. or else meet at a point in the horizontal line, as in Theorem II.

Now, as in the former example, the centre of the picture being determined, the parallels which were perpendicular to it, and also parallel to the plane of the horizon, were, by the help thereof, easily drawn; so in this example following, since the vanishing points are of no less use to draw all parallels, I shall, for this purpose, shew one general rule, without any exceptions; not in the geometrical manner shewn by Dr. TAYLOR, but by the help of the new Theodolite, as now improved by THO. HEATH, Mathematical-instrument-maker, at the Hercules and Globe, near Exeter-Exchange in the Strand.

Let the example be that contained in Plate VI. where, as before, raise the draughts P Q, A Y W, A B W, (A W Y) coinciding with A W B.) fig. 1, 2, 3, and you have the module represented to the eye; raise the drawing a Q perpendicular to the plane of the leaf fig. 4; and it is the plane of the picture designed to be drawn; but it is oblique to each front of the module: and the coin or angle P W is the only part of the module or building, which coincides with the picture. Raise up T E (fig. 5.) as in the former example: and E represents the eye beholding the building or picture. Plant the instrument and a staff in the line S W, which is the ground-line of the picture, or else at equal distances from it, that is parallel to it. And find,

find, as in the foregoing example, the directing number.

Plant the instrument at your designed station T; and rectify it as in the preceding example. Assume the centre C, on the drawing board, draw CV, CX, as before.

Then lay down PW, and its several divisions A', B', &c. and the two points a, b, as in the former example. Draw Pa, and Wb, and produce them till they meet: so shall their intersection V be the vanishing point sought.

Use this point V as you did the centre of the picture in the preceding example; and then go on to draw the front a W as before.

In like manner find the vanishing point Y; and proceed to draw the front PQ.

As to the position of the picture, some persons will have it parallel to a front, others parallel to the diagonal of the plane; others chuse rather that position to which a line drawn from the eye to the common coin PW may be perpendicular to the plane of the picture.

And in this latter, there is no occasion for the directing number, or the bearing of any front: for take T the station at pleasure; bring the index to the beginning of the degrees on the horizontal plate, and turn the whole instrument about till you see thro' the telescope the coin PW, there screw it fast, and level it; and proceed in all respects as in the last example.



S E C T.



S E C T. XIV.

The description and use of the Perambulator, or measuring Wheel.

THIS instrument as it is now made, consists of a light wooden wheel, shod with a thin iron ring, the outside circumference whereof is 99 inches, or half a statute pole; a frame of wood of about three feet long, including the handle and the two cheeks, between which the wheel moves; also a box of about 10 inches diameter, containing a motion work; on the face whereof are three circles, and their indexes or hands; a revolution in the smallest circle answers to the length of one Gunter's chain, a revolution in the greatest circle answers to one mile, and a revolution in the other circle answers to 50 miles. The circle of one chain is divided into 100 equal parts, shewing the links; that of one mile is divided into 320 equal parts, shewing the poles; and the other circle is divided into 50 equal parts, shewing the miles: So that the measure of any distance, run over by the wheel, will be expressed in miles, poles, and links.

The motion of these indices is produced by the rotation of the wheel, whose axis, as it revolves, communicates motion to the work in the box through a groove or channel cut in one of the cheeks.

The length of the instrument, from the extremity of the wheel to the handle, is about four feet and a half; and its weight is about twenty-three pounds, the wood work being of mahogany, and the motion

tion work of brass: But it may be made much shorter and lighter.

To use the perambulator in the measuring of distances.

Being well ascertained of the accuracy of each part of the instrument, open the lid of the box, set all the hands to the mark 0, or beginning of their respective circles, and shut the box; then taking the handle in both hands, drive the wheel before you, directing it towards some fixed point; when the proposed distance is run over, observe the position of each hand, and these being rightly estimated, will give the measure of that distance, reckoning always from the point on which the wheel rests, at the beginning and end, or the point perpendicularly under the axle.

To find the distance run over; observe, first, the mile index; secondly, the pole index; and, thirdly, the link index: If the mile index has not moved one division, the distance is less than a mile; then the pole index will shew the whole poles, and the link index shews the links above the even poles: But, if the mile index has moved one or more divisions, the distance run will be so many miles, and the overplus poles and links will be shewed by their respective indices.

Example I. Suppose the mile index stands between the beginning of its divisions and the first mark; the pole index at 221; and the link index at 0; then the distance run over will be 221 poles, or 55 chains and 25 links, or 5 furlongs and 21 poles.

Example II. Suppose the mile index stands between the 3d and 4th division; the pole index between the 184th and 185th divisions; and the link index

index at its 67th division; then the distance run over will be 3 miles, 184 poles, and 17 links; the other 50 links being equal to 2 poles, are accounted for in the pole circle.

When you have several successive lines to measure, or one great distance, in the rout of which the intermediate distances of several places are to be noted, the three indexes may be set at the beginning of their respective circles, at the commencing each new line or distance; or, which is the better way, do not set the indices anew, but let them continue to revolve, and note at each distance the numbers shewn by the indices; and thus the whole distance passed over in any given time will be at once shewn; then the intermediate distances, which were noted, will be found, by subtracting the numbers entered in the field-book from one another.

To this instrument may be annexed two iron rods, which may lie close under the cheeks, and when wanted may be let down and serve as legs, like those of a wheel-barrow: Also to the cheeks may be fixed two standards, which reaching above the wheel may support a cross piece, whereon a Theodolite, or other surveying instrument may be fixed, whose centre standing over the axle-tree, will always correspond to the place where the line begins, and, consequently, the trouble of setting the head of the three-legged staff over the station-staff hole will be avoided; beside which, a surveyor using such an instrument, will be benefitted in the following particulars.

The tiresome repetition of stooping with the chain or pole will be avoided.

In the trouble of handling the arrows, their account, and the difficulty of sticking them into hard gravelly or rocky ground, or into the ground when frozen.

The expence of one, or both chain-men will be saved.

There can arise no such errors as frequently happen to the chain, such as its swaying, yawing, the difference of pricking down the arrows, or the diversity in the lengths of chains.

The length of a day's journey may be measured without keeping any account, till the end.

In taking the angles of elevation or descent, the Theodolite always stands at the same height from the ground.

A surveyor with one or two assistants, and this instrument, can measure any quantity of land in about half the time he could do it in by any other means.

To the use of this instrument it may be objected, that in going over many plough ridges, or ant-hills, there will be a considerable difference in the lengths given by the chain and wheel; there will, indeed, be some difference, and rather more than will happen in measuring the same distance forwards and backwards by the chain; for, by a trial on a common full of large ant-hills, in the most uneven part thereof, the wheel gave a pole more than the chain, in the length of a quarter of a mile, and going over more than 100 hills; and in measuring this length back again, the wheel gave the same distance; but the chain gave near half a pole more than

than before: Besides, an experienced artist would avoid taking the worst place.

With regard to the objections concerning the passing of rivers, ponds, woods, brakes, &c. they are of small import; for a person of any share of sagacity, will readily know how to proceed on such emergencies.

With regard to the passing of hedges, ditches, gates, &c. and without varying the indices; these are easily answered; for by hasping the wheel, a contrivance to do this being provided, the indices are fixed; and the weight of the whole, though increased by the Theodolite, will not much exceed thirty pounds: But they may be made much lighter; and may be so contrived, both frame and wheel, as to take to pieces for the convenience of carriage, and packed up in the space of little more than a cubic foot.





SECT. XV.

The use of the Universal Dial, and the variation of the Compass.

IT has been supposed, that a needle playing freely, which has had a strong touch from the loadstone, points exactly north and south. But by numberless experiments it has been proved, that the needle does not point exactly north and south, any where but in such places on the earth as lie on one particular line, which is therefore called, The Line of no Variation ; and this line is found to change its situation by a slow motion, from east to west. It now passes from the westward of the Cape of Good Hope to the West-Indies. And the variation of the needle in all other places is known constantly to alter by a slow change. In England that end of the needle which has been supposed to point full north, deviates from it now about 14 * degrees to the westward ; and is still, and also will for many years continue to increase, even till it arrive at its Maximum ; and then will decrease till it vanishes, and then change to the eastward, as it formerly was ; and by an oscillatory change will so continue to alter.

This variation of the needle would no ways hinder the exactness of the survey, if it was constant ; nor is the alteration of the variation capable of mak-

* In the year 1749, the deviation to the westward was about 17 degrees.

ing any sensible error in a survey that is performed in a space of time not exceeding four or five years.

But if the quantity of the variation be not known, and consequently not allowed for, the north point of the compass, which the surveyor draws on his map, will err as much as that variation is. It is therefore convenient in all places to find it; and this may be done several ways: but by none more readily, more easily, or more exactly, than by the universal dial, as now made by Mr. HEATH, the Instrument-maker mentioned before, the figure whereof is in the plate fronting the title.

This dial consists of four principal parts, *viz.* the Foot or Pedestal, the Meridian, the Equinoctial, and the Bridge.

The Pedestal contains a box and a needle, and two cross levels; whereby, with the help of the three screws in the foot, it may be placed truly horizontal; and while the pedestal remains in the situation, the box and the circles of the instrument may be turned round to acquire a proper position of the meridian. The circumference of the box is divided into 360 degrees, and within this is another circle divided into four quadrants, and each numbered with 90 degrees. On the plane of that part of the pedestal which is moveable are segments of circles, containing a table of the equation of time; shewing the months and days of the month, together with the minutes which watches, or equal time-keepers, are too fast or too slow for the motion of the sun: And on the outer margin of this moveable part, is a circle divided and numbered, either into 360 degrees, or into four quadrants, containing 90 degrees each, beginning with 0 degrees, at two points diametrically opposite: This circle slides against the fixed ring of the pedestal, on which is a Vernier's scale, (commonly called Nonius's) for obtaining parts of degrees.

The two scrolls which stand upright on the plane of the pedestal, and support the rings of the instrument, have fixed to them a strong ring, whose plane is at right angles to the division 0 degrees on the plane of the pedestal; within this ring slides the meridian, on one side whereof are engraved the names of places, with their latitudes; and the other side is divided into four quadrants of 90 degrees each: To the upper part of the ring, within which slides the meridian, is fixed an index, on which is a Vernier's scale, serving to shew the parts of degrees on the meridian; and to this piece is fixed a ring, by which the whole instrument may be lifted.

Concentric within the meridian is the equinoctial ring; having on one side the names of some places with their latitudes; on the other side the hours of a day, each divided into every second minute; and the inside of the ring divided in the same manner. This ring turns on two points diametrically opposite, fixed at the divisions XII and XII, and the same points are fixed on the inside of the meridian ring, against the diametrical divisions 0 and 0. The equinoctial ring turning on these points, may be shut up within the meridian ring, or set at right angles to it, beyond which position it is not suffered to pass, there being two pieces fixed to the meridian which stops the equinoctial ring when in the said position.

The Bridge is a strait flat piece, so fixed to the meridian ring as to turn on two points in the direction of the middle of the bridge, and opposite to the divisions 90 and 90 on the meridian. On one side of the bridge are the names of the months, with divisions to every second day; on the other side are the signs of the Ecliptic, with their distances graduated to every second degree; also the degrees and half degrees of declination, north and south; and in the middle of the bridge is a slit, in which is placed a slider, with a hole in its middle.

When

When an observation is made with this instrument, the latitude of the place counted on the meridian according as it is north or south, distinguished by N. and S. must be brought to the index at top ; the slider on the bridge must be brought to either the day of the month, the Sun's declination, or the Sun's place, and then it will accordingly shew the other two : The equinoctial circle must be thrust out of the meridian, till it is at right angles to it. Then bring the beginning of the degrees on the horizontal part of the pedestal to the index there : Turn the whole about upon the three feet, till the Sun shines equally on both faces of the plane of the meridian, the north part of the instrument being towards the north part of the world, and set the horizontal plane level. Then shall the dial be duly rectified for observation.

It may be readily known when the plane of the meridian is directed to the sun's center, by holding a piece of clean paper behind the meridian, and observing that the shade of the fore part of the ring falls just on the breadth of the inside of the back part ; and that the shade on the paper is of the same breadth with the thickness of the ring.

Now keeping the three feet in the same place, turn the dial about, till the spot of light passing thro' the hole in the slider, falls on the circle which is divided into hours, &c. in the middle of the inside of that ring which represents the equinoctial ; which will be among the morning hours, if before noon ; and among the evening hours, if after noon ; then will the dial shew these following very useful and pleasant problems.

I. The spot of light points out exactly the hour of the day.

M 4

II. The

II. The circle representing the meridian, lies exactly in the plane of the celestial meridian; and so a thread stretched over either face of it, draws a true meridian line.

III. The middle of the bridge points exactly to the true poles.

IV. The needle in the box shews the variation by the distance of its end from the beginning of the degrees there marked; and is westward, if the north end of the needle be to the left-hand of the beginning of those degrees, but eastward when to the right.

V. The index on the horizon, points out the Sun's Azimuth, which is to be reckoned from east or west, if the circle on the horizontal plane is divided into four nineties.

VI. Turn the meridian about the plane of the horizon, till the Sun shines equally on both its faces as at first, the three feet still standing in the same place, and move the meridian towards or from the Sun, till the spot of light coming thro' the hole in that sight which has the cross hairs in it, falls exactly on the little hole in the other sight which will then be undermost; and the index in the Zenith, points to the Sun's altitude, among the divisions of the meridian.

By this instrument, may the position of any wall be thus found: Let a strait broad ruler, whose sides are parallel, be applied to a wall, on which a vertical dial is designed to be drawn, and the two feet of the dial marked A, A, be applied to the other edge of the ruler; then let the dial be rectified to the latitude of the place, with the day of the month, be

be levelled, and the upper part of the instrument turned about till the spot of light fall as before; then the index on the horizon will give the situation of that wall, usually called by diallers, The declination of the plane. Or, if the sun does not shine, apply the legs A, A, to the ruler, keep them in that position, and turn the upper part about, till the north end of the needle points at the variation; and then will the index on the pedestal shew the situation.

This curious instrument is of great use for the regulation of clocks and watches, by the help of the apparent time observed by it (as shewn above) and the equation of time engraved on the horizontal part of the pedestal.

It is also a very ready instrument for seating an horizontal dial duly: For after the apparent time is found by it, and the horizontal dial so seated, that it may be turned about, and still be parallel to the horizon; then move it round, the sun shining thereon, till it shews the same hour that the universal dial shews, and then it is truly placed, and may be there fixed to the pedestal.

And because the latitude of the place where the instrument is used, must be known, there is engraved on the back side of the meridian, or the under side of the pedestal, the latitudes of the cities, and most remarkable towns in England, and other parts of Europe.

But if any gentleman pleases to communicate to the workman, the latitudes of his country seats, they may be particularly laid down on it.

Or if any gentleman about to travel, is pleased to communicate the tour he designs to take, he may have a catalogue of the towns in his way, and their latitudes, from Mr. HEATH, with the instrument, in order to ease him of the trouble of searching maps, globes, or geographical books.

The

The variation of the needle may be found by the Theodolite, thus: Take the bearing of the sun exactly at 12 at noon, and the north end of the needle gives the variation.

Or, take the bearing of the Sun, either at the time of rising or setting; and then, say: As the sine of the complement of the latitude, is to the sine of the declination; so is the sine of 90 degrees, to the sine of the Sun's distance from the east at rising, and from the west at setting; and is always southerly, when the declination is south, and northerly when north. And as much as this distance differs from that observed by the instrument, so much is the variation: And if the bearing taken by the instrument be to the left-hand of that calculated, it is westerly, otherwise easterly.

Or it may be found, by an horizontal dial, duly seated, without the sun; if you stretch a thread on that dial's meridian line, and the instrument placed near it, you turn the index about, till the telescope is parallel to that thread; for then the bearing shewn by the north-end of the needle, is the variation.

Beside the preceding uses of this universal dial, it may, with a very small addition, be applied in all respects as a Theodolite, or Circumferentor; or this dial may be aptly and easily mounted on a Theodolite, and be taken off at pleasure.

There is one inconvenience usually attends the use of these instruments, which in this may be remedied: From about an hour before, to an hour after noon, the passage of the spot of light over the equinoctial, forms with it so acute an angle, that it is not very easy to observe the point where it crosses it; and, consequently, the preceding problems cannot be so exactly performed. And just at noon, the thick-
ness

ness of the brass shades the slider and bridge; and so no observation at all can be made.

In this case, bring the beginning of the degrees to the index on the horizontal part, and let the hour be taken by the instrument some time before, which is remote from noon, whether before or after, on the board of the window of your study, where you design to use it; the index all the while pointing to the beginning of the degrees. Lay a strait ruler to touch the feet marked A, A; and by its edge, draw on the window-board a strait line, or make two points where that strait line should be drawn: And then, at any time that is very near noon, by laying the ruler to the line or points, bringing the beginning of the degrees on the horizontal part of the pedestal to the index, and applying the feet A, A, to the edge of the ruler, as before; if you rectify the instrument to the latitude and day, you may see the true time either before or after noon; and just at noon, the middle of the under part of the meridian will be shaded by the upper; and consequently the time of noon, is known, and determined, whether it be before or after noon.

If you are in a strange place, and the time be very near noon, level the instrument, and turn it about till the north-end of the needle points at the variation, and then it is duly placed, and you may work as in the last.

Much more might be said of this instrument's use, but my designed brevity will not permit me to enlarge any farther thereon.

The latitude of a place may be found by the common Theodolite, thus: Turn the plate of the instrument so that it be in a vertical position, in the plane of the meridian, which may be readily known by applying to the plate a string and plummet; with this position, set the fixed sights horizontal, either
by

by a level, or by the thread of a plummet cutting the degree at right angles to the fixed sights; then a little before noon move the index so that the Sun's rays passing thro' the hole in one sight, the spot may fall directly on the middle line of the other sight; and the degrees cut by the index will shew the Sun's altitude at that time: As the Sun mounts higher, the spot will descend on the sight, therefore keep the index moving so as to stay the spot on the line, until the spot be observed to begin to rise above the line, then observe the degrees cut by the index, and they will be the meridian altitude, and their complement to 90, will be the Sun's zenith distance; which on this side the tropic of Cancer must always be named south.

Now having the Sun's meridian zenith distance, and his declination taken from tables, the latitude of the place may be found by this

RULE. If the zenith distance and declination have contrary names, their sum gives the latitude sought, of the same name with the declination.

But, if the zenith distance and declination have the same name, the difference will be the latitude sought, of the same, or a contrary, name with the declination, as it is greater, or less, than the zenith distance.





SECT. XVI.

A Treatise on the Use of the Pantographia, or Imitator, invented by HEATH and WING, Mathematical and Optical Instrument-makers, near Exeter-Exchange in the Strand.

THIS instrument consists of four rulers, two large and two small: The two great ones are joined at one of their extremities by a joint, or centre, about which they are easily moveable. At the bottom of this joint is a little roller or caster, whereon the instrument is to bear: One end of each of the two small rulers are pinned near the middle of each great one, and the other ends fastened by a joint, so that in what manner soever the instrument is moved, the four rulers always form a parallelogram, having two contiguous sides about as long again as the other two sides.

The two longer, and one of the shorter rulers have each a box fitted to them, that may be moved and fixed to any part of the said rulers, by means of a screw fixed to the box. These boxes have each a cylindric hole, wherein may be alternately put three things; namely, a tracing-point, a portcrayon, that rises and lowers of itself, according to the unevenness of the plane worked upon; and a fulcrum that screws into the table, the top whereof is a cylinder fitting one of the boxes: This fulcrum is the fixed point round which the instrument moves, when used to copy with. There are also other casters on which the rulers rest, serving likewise to facilitate their motion. On these rulers are divisions with figures, shewing where to place
th.

the chamfered, or bevel edge of the boxes, according to the intended reduction.

This instrument is convenient for such who are conversant in the art of drawing, as well as for those who have made but little progress therein; for with it may be nearly taken, with great ease and accuracy, the copies of all manner of designs, whether figures, ornaments, plans, geographic carts, and such like, reducing them from a larger size to a smaller, or from a smaller to a larger. The reference in what follows is in plate VII, where the three boxes are marked by the letters A, B, D.

To use the Pantographia.

First, Having determined the proportion that is to be between the original and copy, set the bevel edge of the boxes B and D to the division expressing that proportion, there screw them fast, and fix the edge of the box A to the line C.

Second, Screw the fulcrum into some convenient part of the board on which the operation is to be performed.

Third, Put the fulcrum into the whole of the box B, the crayon into that of D, and the tracer into that of A, when the copy is to be less than the original; but when larger, put the crayon into A, and the tracer into D.

Fourth, open the instrument somewhat, fix the original under the tracer, and clean paper under the crayon; then, while a steady hand moves the tracer over the lines of the original, the crayon or pencil will draw the copy required.

The

The divisions or ratios thought proper to be placed on the rulers B and D of this instrument, are $\frac{1}{2}$, $\frac{2}{3}$, $\frac{1}{4}$, $\frac{3}{5}$, $\frac{1}{6}$, $\frac{4}{7}$, $\frac{2}{8}$, $\frac{1}{9}$, $\frac{3}{10}$, $\frac{1}{11}$, $\frac{1}{12}$; and $\frac{2}{3}$, $\frac{4}{5}$, $\frac{5}{6}$, $\frac{6}{7}$, $\frac{7}{8}$, $\frac{8}{9}$, $\frac{9}{10}$, $\frac{10}{11}$, $\frac{11}{12}$; these numbers denote the proposed ratios between the copy and original; thus, if the copy is to be half the length and breadth of the original, the boxes B, D, and A, are to be set at the divisions $\frac{1}{2}$ and C; then the fulcrum is to be put into B, the crayon in D, and the tracer into A: If the length and breadth of the copy is to be $\frac{2}{3}$ of those of the original, the boxes B and D are to be put to the divisions $\frac{2}{3}$, the box A, remaining at the mark C, where it is to be set in every operation; the fulcrum to be put into D, and the crayon into B. And in like manner any other diminution, within the limits of the divisions, may be readily performed.

When the copy is to be increased in any ratio expressible by one of these numbers, the boxes B and D are to be set to that number as before; the fulcrum put in B, the tracer in D, and the crayon in A; then the picture being put under the tracer D, and the clean paper under the crayon A, the copy may be taken as before.

When the copy is to be of the same size as the original, fix the bevel edge of the boxes B and D, to the marks $\frac{1}{2}$, and the box A to the mark C; put the fulcrum into the box D, the crayon into B, and the tracer into A; then will the crayon B move over equal lines and spaces with the tracer A, and, consequently, delineate a copy equal in size to the original.

And thus may any picture be accurately copied without damaging it in the least; for the tracer may be passed over the lines without pressing on them, or even touching them: But that this business of copying may be rendered as perfect as can be desired, it will be necessary to be more circumstantial in

in describing the use of this instrument, particularly some appendages and cautions not yet mentioned.

In plate VII. fig. 1. represents the plan of the instrument, with all the divisions; figure 2 is a perspective view of it on a table, in the proper position for use. The boxes A, B and D are placed for reducing the original to one third of its size, or as 1 to 3, shewn in the figure. The fulcrum I, screwed into the table, is placed in the box B; this fulcrum, as hitherto described, is fixed, but a moveable one may be substituted in its room, as shall be shewn hereafter.

Over fig. 2, the different pieces fixed to the rulers are severally represented. The figures A and B represent the two boxes. E is the tracing point that fits in the socket N, fixed to the boxes A and B. These sockets has a little screw O, serving to fix the tracing point when set in the boxes, at the proper height.

Figure F is the tube for the port crayon. G is the port crayon to be put into the tube F; it has a small filken string fixed to it, serving to raise the crayon or pencil, so that it may not touch the paper while it is moving from one place to another. This string is thus used; when the crayon is in the box D, pass the loose end through the holes in the upright pieces fixed at Z, S, X, fig. 2; then taking the end into the hand holding the box A, the crayon may be raised with the greatest ease, whenever it is wanted, even while the instrument is moving. But if the crayon is put into the box A, then the loose end must pass through the holes in the pieces X, S, Z, and so to the hand, which in this case will have hold of the box D.

The string is represented in fig. 2. its length is always the same, however the boxes are placed, because it follows the direction of the rulers.

The

The cup H above the port crayon G, screws on its upper part, and serves to increase the weight of the crayon or pencil, making it press harder on the paper when necessary ; this is done by putting in leaden shot, or any such like weight.

The little wheel, or castor L, that has a double slit or groove, x and y, is fixed to the ruler B by the under groove x, when the crayon is put into the box B. But if put into D, the castor or wheel L, then slips on the ruler D by the upper groove y. M is a wheel or castor to be put on the ruler A.

The fulcrum, screwing to the table, as mention'd in the foregoing description, and represented in fig. 2. being proper only to copy subjects of a middling size ; a moveable fulcrum represented by fig. P, is to be used when the picture is large. This fulcrum is a piece of lead of sufficient weight to prevent its being displaced by the motion of the instrument. In the middle thereof is screwed a pin K like the fixed fulcrum I. The figure R is a little collar, serving equally to either the fixed or moveable fulcrum, on whose pin it is put when either of them is placed at the box D : But is not used when placed at the box B, because this is less distant from the table. Little collars, of different heights, are also used in the same manner to K and I ; the use thereof depending on the prudence of the operator, taking care that the motion of the instrument be performed with the utmost freedom.

With this moveable fulcrum a picture or drawing of any dimension may be copied : For the picture being made fast on any table or plane, the fulcrum must be so situated that a part thereof may be copied as far as the instrument can extend at that time. Then on the picture and paper mark three corresponding points on each, to serve as references for finding the position of the fulcrum in the copy, relatively to what has been already drawn ; move

N

the

the fulcrum towards the picture, and when the three points on each are found to correspond, fix the copy in that situation with a little soft wax; then continue drawing as far as the instrument can extend as before, repeating this operation till the whole is copied.

The usefulness of this moveable fulcrum is easily perceived; for if towards the end of the operation both the copy and fulcrum should rest on the picture, it would be no inconvenience as they no ways damage it. By this means also the extraordinary length of the rulers is prevented, which are generally but of about two feet and a half; a greater length would render them inaccurate, because they would then be more subject to bend and spring.

It may happen, on account of the size of the paper, or otherwise, that the copy will not be in a proportion to the original, expressible by any of the divisions on the instrument; in such case a method must be found to do without, by placing the crayon, tracer and fulcrum in a position answering to the relative dimensions of the original and copy.

In order to which it is necessary to observe, that the fundamental principle, on which depends the accuracy in operating by this instrument is, that the fulcrum, crayon, and tracer, are always to stand in a right line, in every position of the rulers; whenever they are so, the copy will truly represent the original. By the following method it will be known if those three points stand in a right line.

Let the fulcrum, crayon, and tracer, be included between a doubled thread, as in the figures marked 1, 2, 3, standing under the instrument marked fig. 1; Hold these threads fast at the mark 3, and if the points are not in a right line, the thread will be bent at the box D, marked 2; this box must then be moved till the threads become parallel, by touching

touching both sides of the three cylinders, which will then be in a right line.

This principle being observed in the position of the above-mentioned points, let there be given a picture or drawing of any dimension to reduce to a size that is no aliquot part or parts of the original; then operate in the following manner.

Examine, first, if the given size is greater or less than half the original.

When less, always place the fulcrum in the box B, the crayon in the box D, and the tracer in A; these points being brought to a right line as before-mentioned, run over with the tracing point A, the whole length or breadth of the original in a strait line; then examine whether the line made by the crayon agrees with the size given.

If not, and that the space run through by the crayon is less than the given size, bring the box B nearer to the line B on its ruler, and the box D nearer the line D on its ruler.

If, on the contrary, the line traced by the crayon be greater than the given size, bring the two boxes B and D towards the junction Z of the rulers B and D; and, by trials, the proper extent will be found.

By this method, a drawing of any dimension may be copied on any given size, without regard being had to the divisions on the ruler.

If the given size be greater than half the original, then the fulcrum must be placed in the box D, and the crayon in the box B.

When the picture is so large that the instrument cannot extend to its limits, then a third, fourth, &c. part may be taken, proportioning the parts of the copy to those on the original; and working according to the foregoing directions, an accurate reduced copy thereof may be obtained.

To find the divisions on the legs S B, S D.

Let the lines A B, A C, E G, G H, (fig. 4. Plate VII) represent four rulers, so connected together, that in any position of A B, A C, there may always be formed a parallelogram, whose sides are A E, E G, G H, H A.

Now if A C is of any fixed length, and the ratios of A E and E D to A C be assumed, and through D be drawn the right line C D, meeting A B in B.

Required the length of A B.

Let $A C : A E :: a : c$. Then $A E = \frac{c}{a} \times A C$.

And $A C : E D :: n : m$. Then $E D = \frac{m}{n} \times A C$.

Now $C F : F D :: E D : E B$, by similar triangles.

Or $A C - E D : F D :: E D : A B - A E$.

Then $A B - A E = E B = \frac{F D \times E D}{A C - E D}$.

Put $A C = r$. Then $A E = \frac{c}{a} r$; and $E D = \frac{m}{n} r$.

And $r - \frac{m}{n} r : \frac{c}{a} r :: \frac{m}{n} r : A B - \frac{c}{a} r$. Therefore

$$A B \times r - A B \times \frac{m}{n} r - \frac{c}{a} r r + \frac{m c}{n a} r r = \frac{m c}{n a} r r.$$

Therefore $A B \times r - A B \times \frac{m}{n} r = \frac{c}{a} r r$.

Consequently $A B = \frac{n}{n-m} \times \frac{c}{a} \times r$.

Hence

Hence $AB = \frac{1}{2} r \times \frac{n}{n-m}$, when $AE = \frac{1}{2} AC$.

Also $AB = \frac{1}{2} \times \frac{n}{n-m}$, when $AC = 1$.

If the ratio of AE and AB to AC were assumed, to find ED .

Then $AB : AC :: EB : ED$.

Or $AB : AC :: AB - AE : ED$.

Let $AB : AC :: s : t$. Then $AB = \frac{s}{t} AC$.

And $\frac{s}{t} AC : AC :: \frac{s}{t} AC - \frac{c}{a} AC : ED$.

Or $\frac{s}{t} r : r :: \frac{s - \frac{c}{a}}{t} \times r : ED$.

Therefore $ED = \left(\frac{s - \frac{c}{a}}{s} \right) 1 - \frac{t}{s} \times \frac{c}{a} \times r$.

Hence $ED = 1 - \frac{t}{s} \times \frac{1}{2} r$, when $AE = \frac{1}{2} AC$.

Also $ED = 1 - \frac{1}{2} \times \frac{t}{s}$, when $AC = 1$.

And hence the numbers in the following table were found. Where ED in the first column, and AB in the third, are each compared to AC , their ratios being expressed by the numbers in those columns; and the numbers in the second and third columns, are related to AC as the unit; AE being supposed equal to $\frac{1}{2} AC$.

A TABLE for the divisions of the Pantograph.

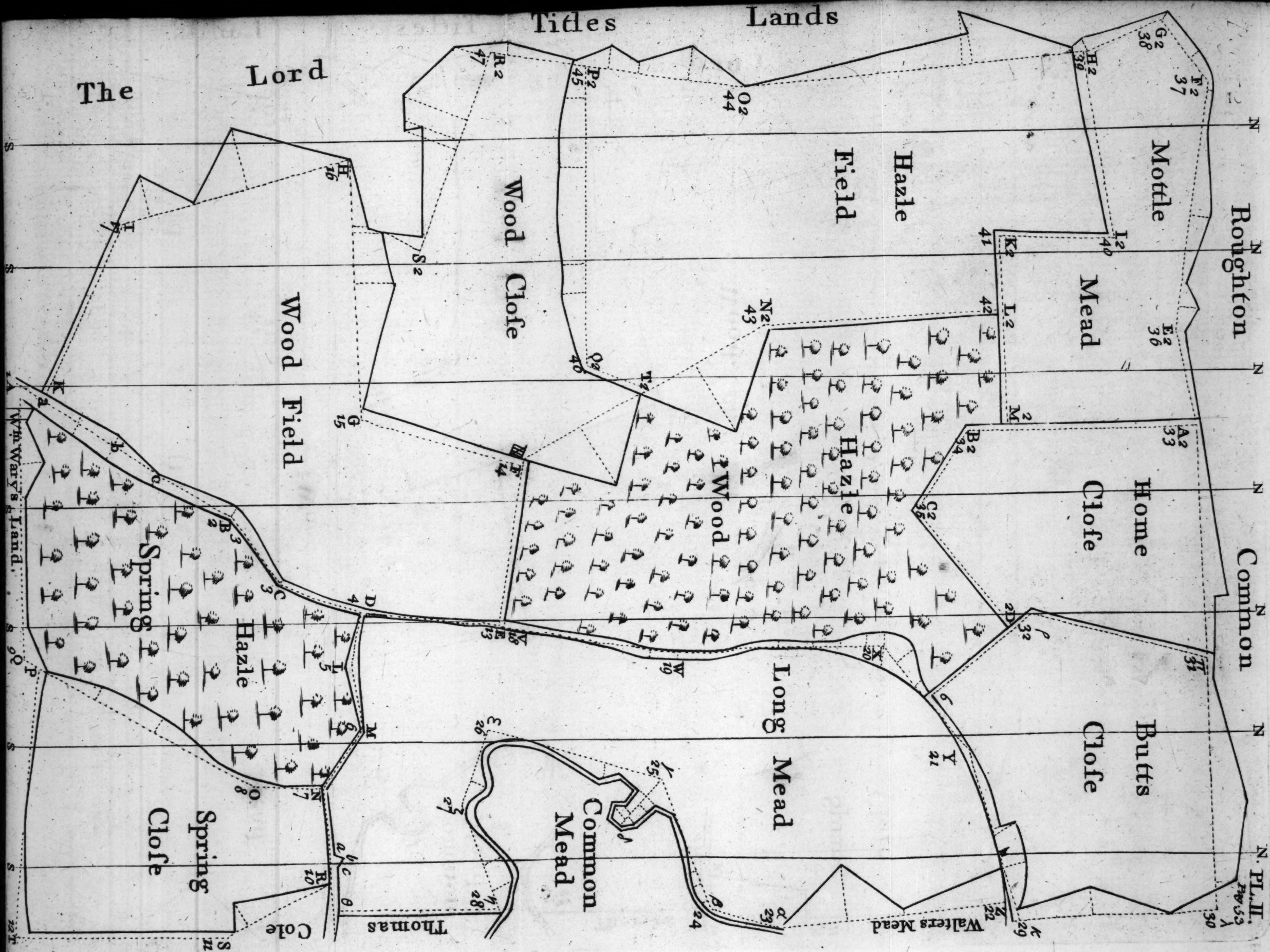
When ED is	Then AB is	When AB is	Then ED is
$\frac{1}{2}$	1,	$\frac{2}{3}$	0,25
$\frac{1}{3}$	0,75	$\frac{3}{4}$	0,3333
$\frac{1}{4}$	0,6666	$\frac{4}{5}$	0,375
$\frac{1}{5}$	0,625	$\frac{5}{6}$	0,4
$\frac{1}{6}$	0,6	$\frac{6}{7}$	0,4166
$\frac{1}{7}$	0,5833	$\frac{7}{8}$	0,4285
$\frac{1}{8}$	0,5714	$\frac{8}{9}$	0,4375
$\frac{1}{9}$	0,5625	$\frac{9}{10}$	0,4444
$\frac{1}{10}$	0,5555	$\frac{10}{11}$	0,45
$\frac{1}{11}$	0,55	$\frac{11}{12}$	0,4545
$\frac{1}{12}$	0,5444		

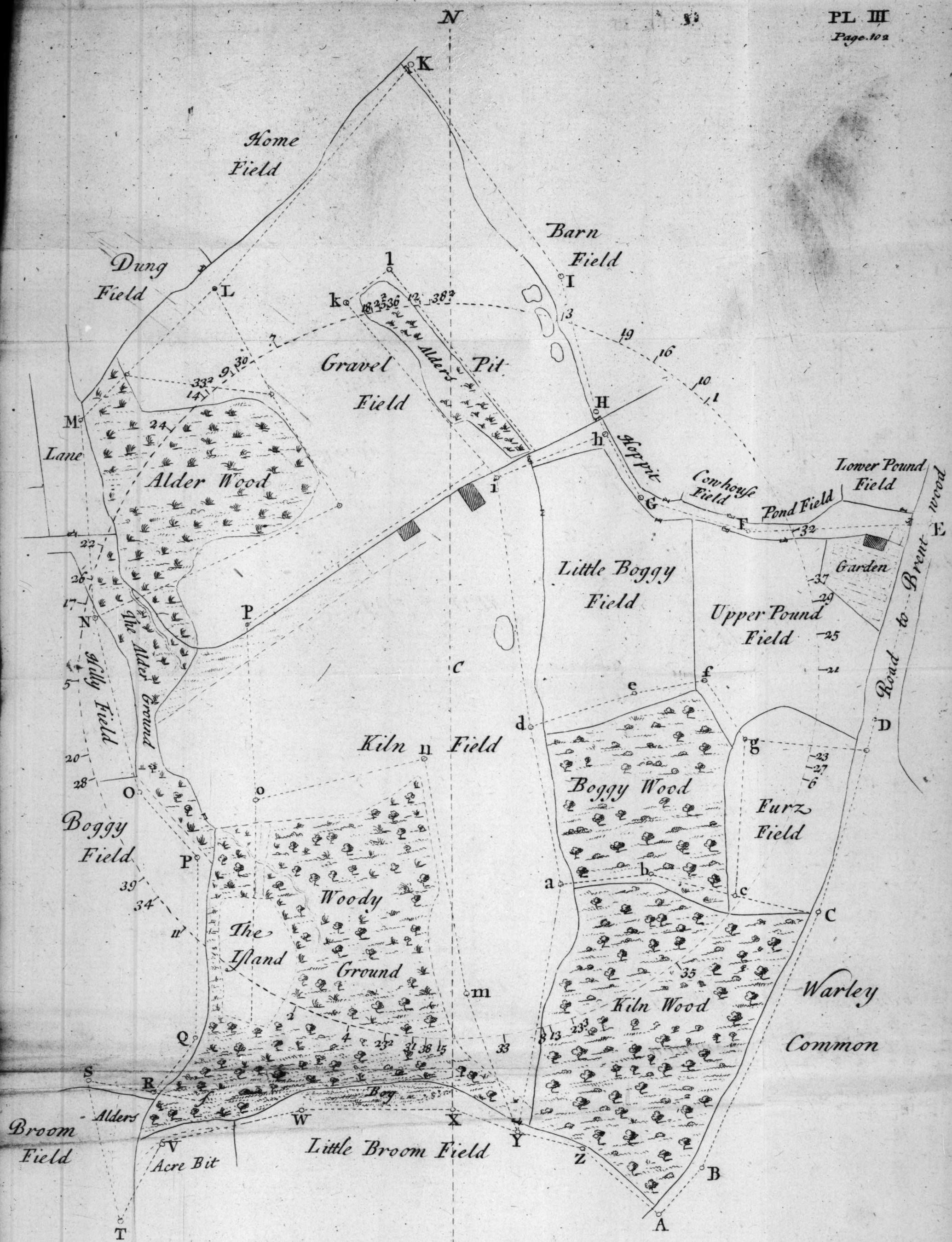
When the ratio of the copy to the original is found in the first column, the tracer is to be in A, the crayon in D, and the fulcrum in B, if the copy is diminished ; but, if increased, the tracer and crayon change places.

And if the ratio of the copy to the original is found in the third column, then the tracer is to be in A, the crayon in B, and the fulcrum in D, if the copy is diminished ; but if the copy is to be increased, the tracer is to be put into B, and the crayon into A.

F I N I S.

Titles	Lands
1. [illegible]	[illegible]
2. [illegible]	[illegible]
3. [illegible]	[illegible]
4. [illegible]	[illegible]
5. [illegible]	[illegible]
6. [illegible]	[illegible]
7. [illegible]	[illegible]
8. [illegible]	[illegible]
9. [illegible]	[illegible]
10. [illegible]	[illegible]
11. [illegible]	[illegible]
12. [illegible]	[illegible]
13. [illegible]	[illegible]
14. [illegible]	[illegible]
15. [illegible]	[illegible]
16. [illegible]	[illegible]
17. [illegible]	[illegible]
18. [illegible]	[illegible]
19. [illegible]	[illegible]
20. [illegible]	[illegible]
21. [illegible]	[illegible]
22. [illegible]	[illegible]
23. [illegible]	[illegible]
24. [illegible]	[illegible]
25. [illegible]	[illegible]
26. [illegible]	[illegible]
27. [illegible]	[illegible]
28. [illegible]	[illegible]
29. [illegible]	[illegible]
30. [illegible]	[illegible]





Plotted by a Scale of 3 Chains or 12 Poles to an Inch

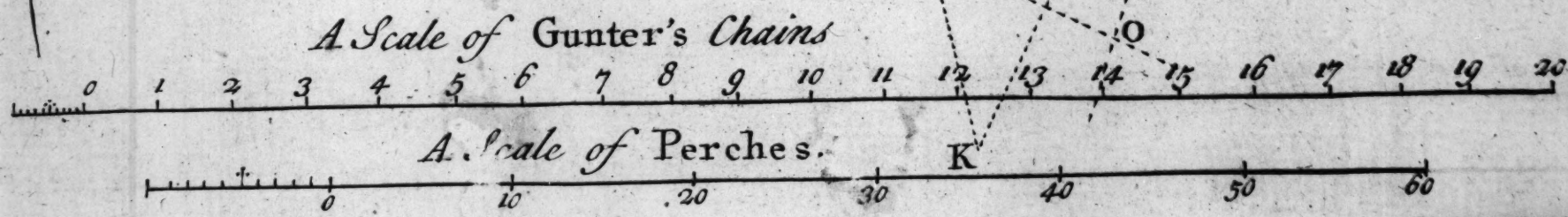
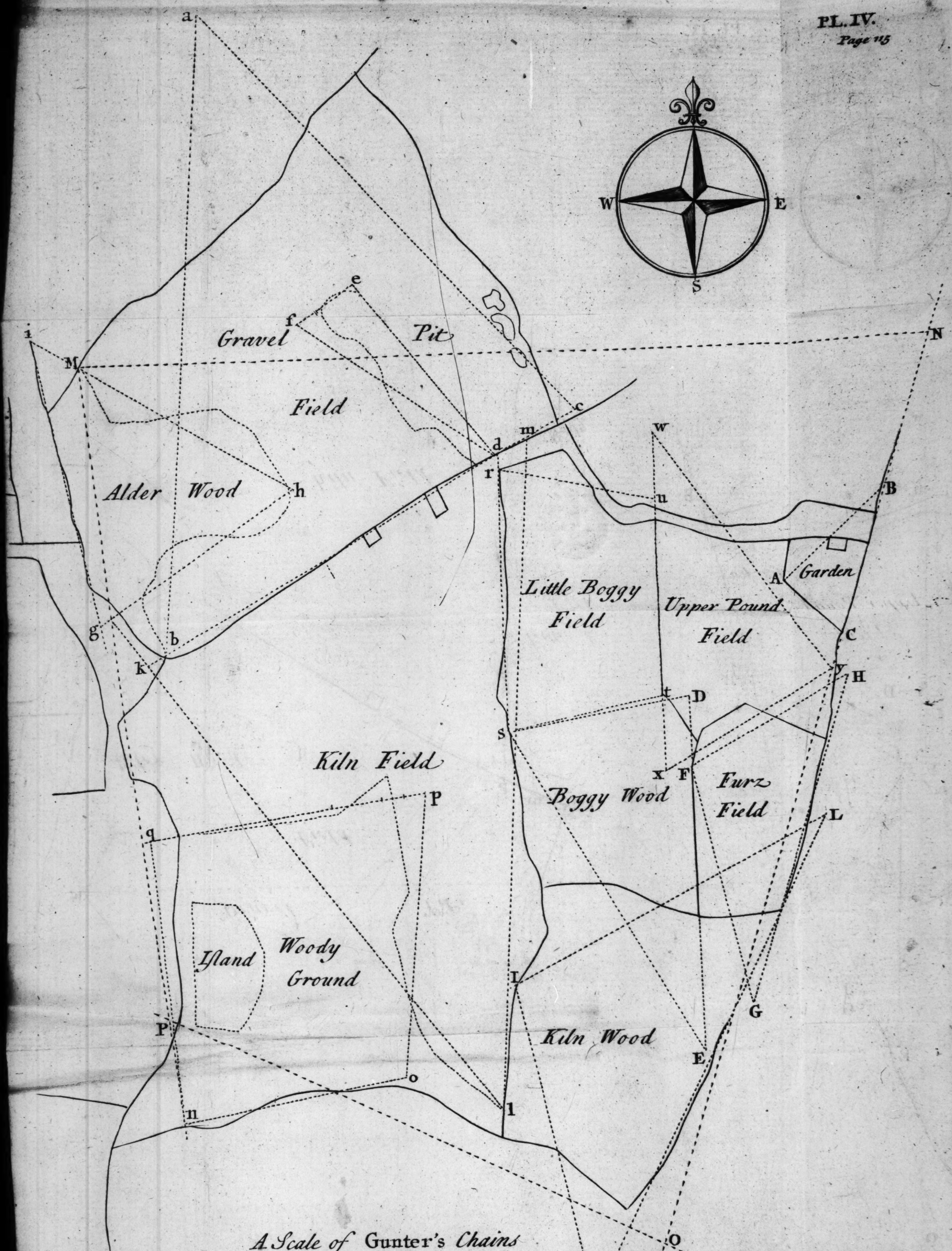
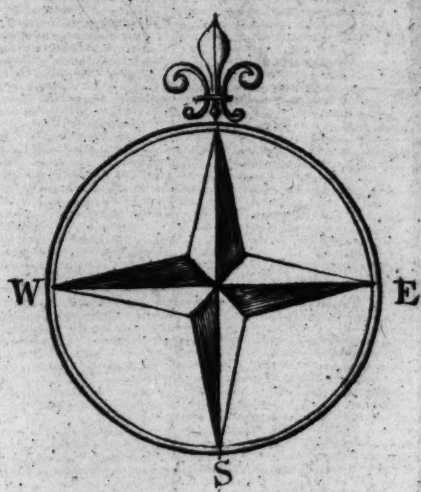
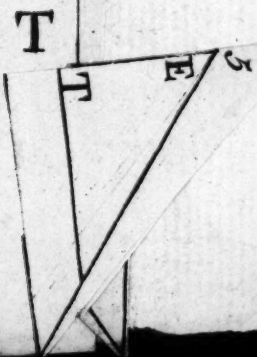


Fig. 4.



B

V

P

Fig. 1

R

A'

B'

C'

D'

W

M'O'

Q'N'

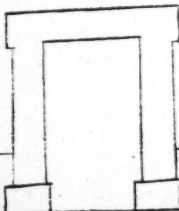
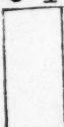
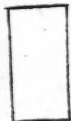
E'

F'

G'

H'

K



A

C E



G I



L N



Fig. 3

B

D F

H K

M O

W

W

Y

A

Fig. 2

Fig. 4

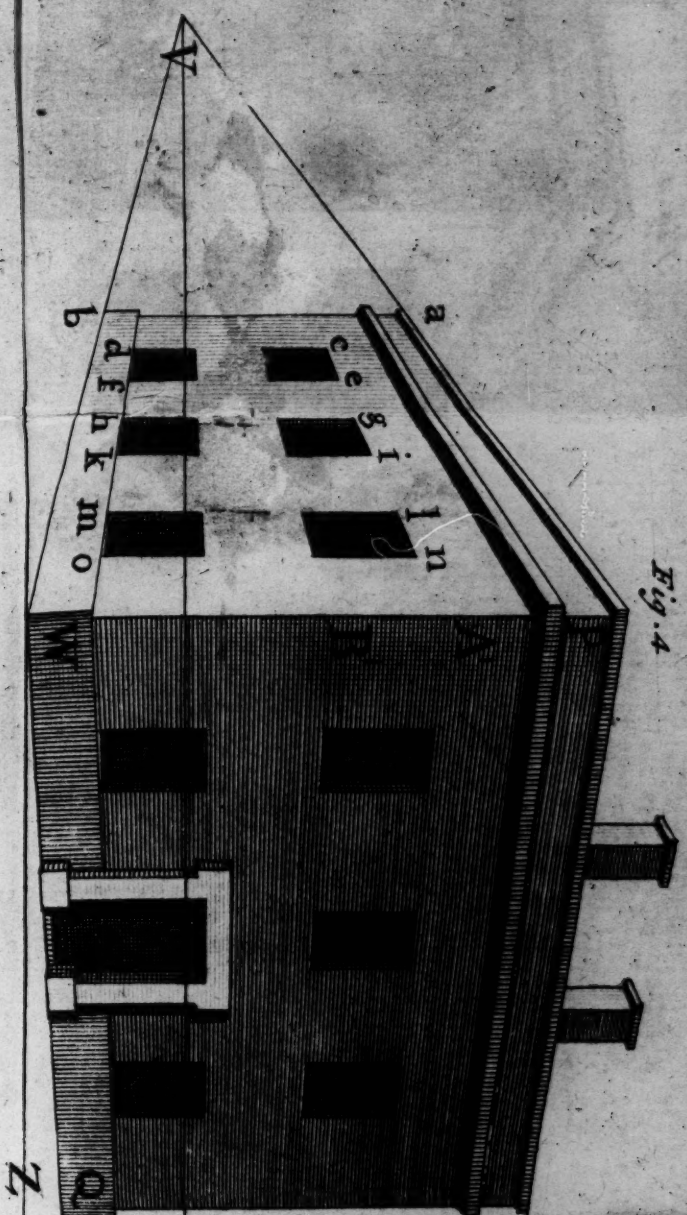




Fig. 1

P

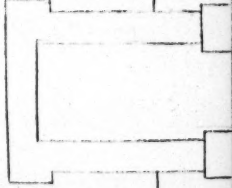
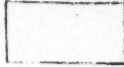
S

A'

B'

W

Q



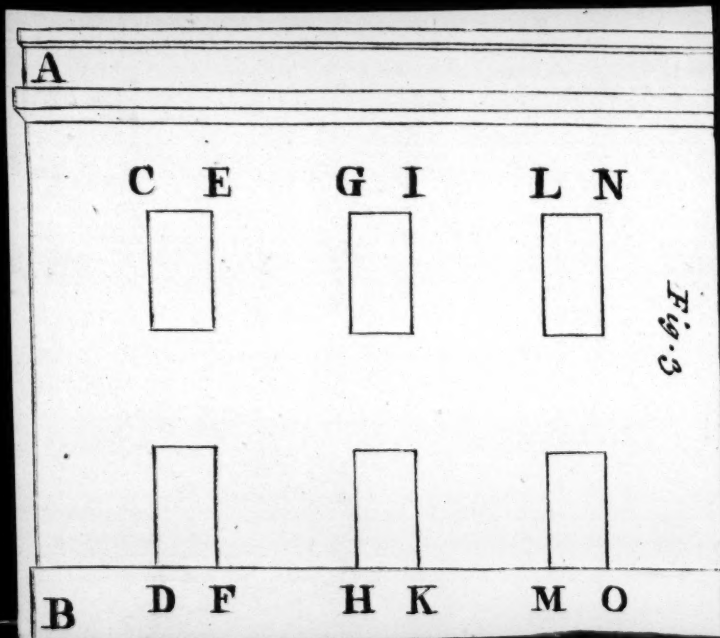


Fig. 3

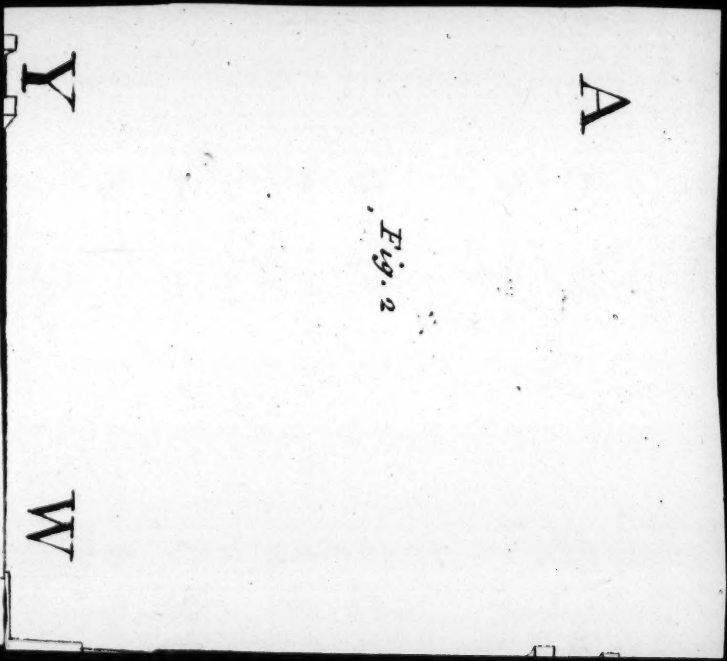
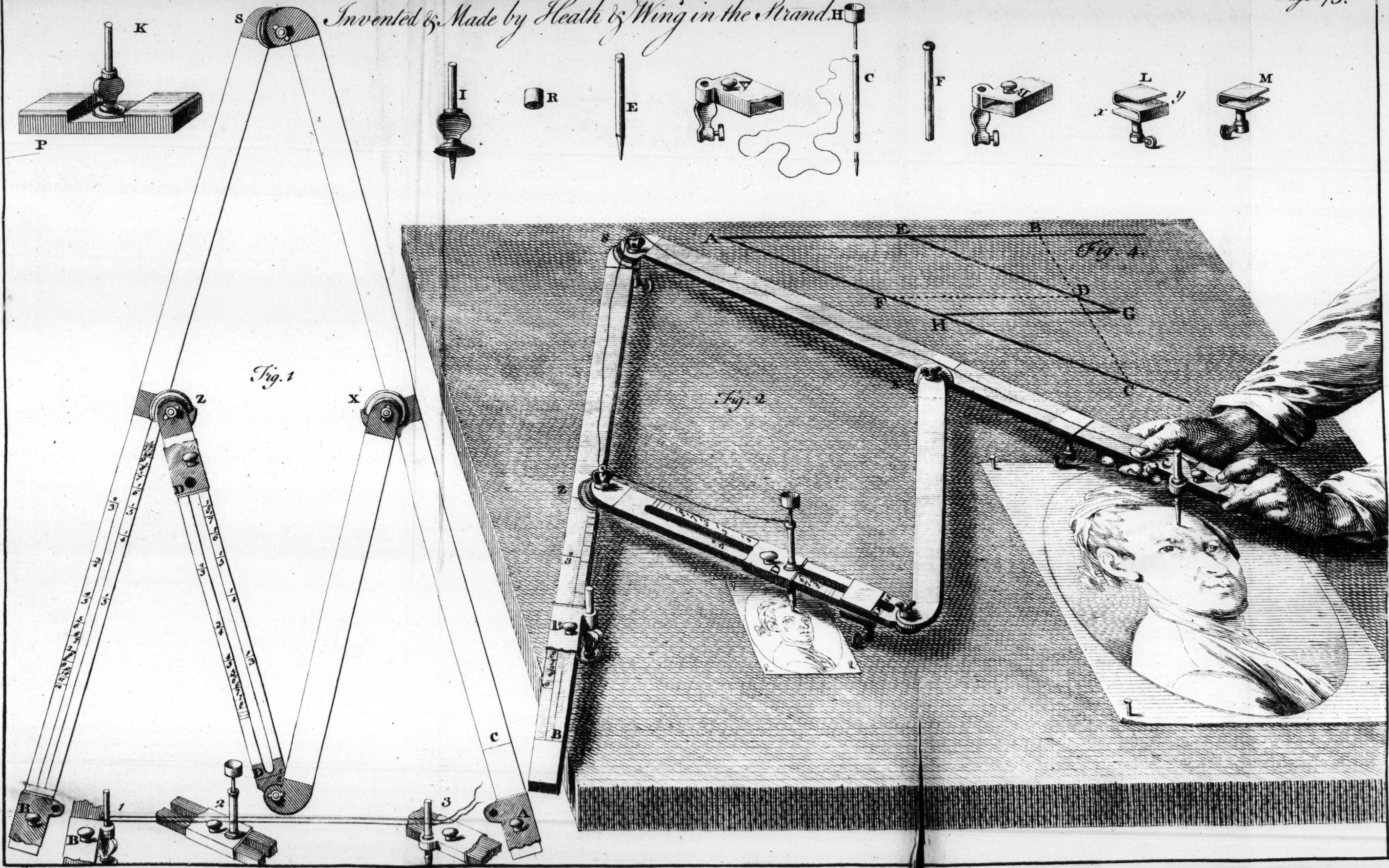
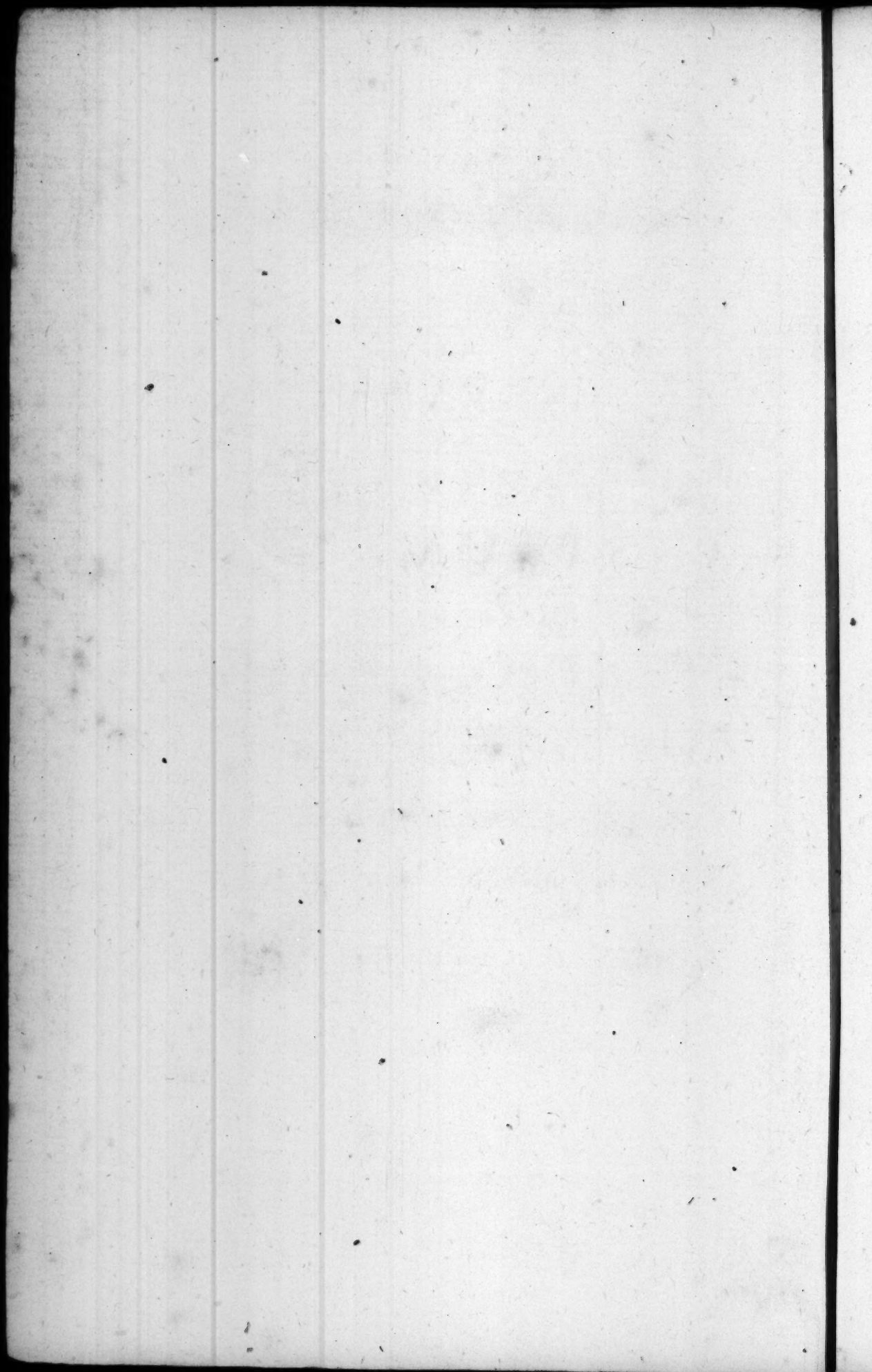


Fig. 2

Invented & Made by Heath & Wing in the Strand.





[1]



MATHEMATICAL,
PHILOSOPHICAL,
AND
OPTICAL
INSTRUMENTS

MADE and SOLD by

HEATH and *WING*,

Near EXETER-EXCHANGE, in the STRAND,
LONDON.



INSTRUMENTS *for* Geometry-
Drawing, &c.

VARIETY of Pocket Cases of Drawing
Instruments, in Silver, Brass, &c. con-
taining

Plain Compasses for measuring Lines, &c.

A

Drawing

Drawing Compasses, with the moveable Points.

Drawing Pen, either with or without a protracting pin,

A Sector, either of Box, Ivory, Brass, or Silver.

A Plain Scale.

A Parallel Ruler.

A Protractor of Brass.

In the best Cases the Compasses are always made with Steel Joints, and the Nibs of all the Pens are made to turn up with a Joint, in order to clean them, in which are also sometimes put a Pair of Hair Compasses, so contrived on the Inside of one of the Legs, that an Extent may be taken to an Hair's Breadth, and a Pair of small Boxes for small Circles.

In a Magazine Case of Drawing Instruments is generally contained all the above Instruments together, with the following Particulars:

A Pair of strong Compasses, with Calliper and Cutting Points.

A Pair of Beam Compasses for drawing larger Circles.

A Pair of proportionable Compasses of a new Contrivance.

A Pair of Triangular Compasses.

A Pair of Quadrangular Compasses.

A Pair of Compasses with two Pair of Points, whose shorter Legs are, at all Openings, always half the Distance of the longer one.

A Pair of Plot Compasses for measuring Charts.

A tracing Point and long Feder.

Elliptical Compasses for drawing Ellipsis or Ovals.

A Bow for drawing curved Lines.

A large Plain Scale, } Sometimes these are
A Plotting Scale, } all made in one In-
A Protractor, } strument.

Plain and Parallel Rulers of several Sizes.

Bottles and Shells of Water Colours.

Ivory Pallats for Indian Ink and Colours.

A Pair of Gunner's Callipers of a new Improvement.

In these Magazine Cases, Gentlemen may have what Number of Instruments they think proper.

RULES *of all* SORTS.

Carpenter's Rules, folding Rules, Coggeshall's sliding Rules for measuring timber, Scamozzi's Rules, Everard's sliding Rules for Gauging, Leadbeater's sliding Rule, Bremer's Rule, Malt Canes, Dimension Canes, Four Foot Gauging Rules with Joints, Five Foot ditto, Tape Boxes, Five Foot Rods for measuring Brick Work, Wainscoting, Painting, &c. in a Walking-stick.

Horse Measures in Sticks or Canes.

SURVEYING INSTRUMENTS.

A plain Table with Index and Sights, whereby the Draught or Plan is taken on the Spot.

Plain Tables, improved with an Index of a peculiar make, whereby the Line of Sights in viewing is always over the Center of the Table, which also is readily set over the Station Hole, the Station Lines are likewise drawn parallel to those measured on the Land, and the Table is set horizontal by a Spirit Level.

Theodolites, for measuring Angles, Distances, Altitudes, &c. Those Instruments are made various Ways; some being more simple and portable; others more accurate and expeditious.

The Plain Theodolites, which consists of four plain Sights, two fastened to the Limb, and two on the Ends of the Index, with a Compass on the Index-Plate, divided into Degrees; and the Limb subdivided into Minutes by a Nonius's Division; the Whole upon a Ball and Socket, and that placed upon a three-legg'd Staff.

Theodolites of the latest Improvements, by T. HEATH. This Instrument has a Spirit Level affixed to the Telescope, and another, at Right Angles thereto in the Box; by Means of which cross Levels, and the Help of four Screws playing between two Plates in the Brass Head of the Staff, the Plate, or limb

Limb of the Instrument, is readily brought to a true horizontal Situation; the Telescope, with cross Hairs therein, turns on an Arch, fixed to the Index perpendicular to the Plate of the Instrument; the Arch is of the same Radius as the Plate, and the Telescope may be elevated or depressed thereon quite to a Quadrant, or 90 Degrees: On this Arch are graduated the Degrees of a Circle, which are numbered from the Vertex either Way, with 10, 20, &c. and are cut by an Index under the Telescope, divided after Vernier's, commonly called Nonius's Way, like those on the Limb of the Instrument: Within the Degrees are two Lines, numbered with 10, 20, &c. down to 100, and cut by the Edge of the Index, on the Right whereof is graven Elevation, and on the Left Depression. These Lines serve to shew the Altitude or Depression of any Object in 100th Parts of the Distance at which the Instrument is planted to take the Observation; and are useful in finding the Height of a Tree; in the measuring of Timber standing; as also to find the Altitudes of the several Parts of a Building, in drawing the Perspective Appearance thereof.

Circumferentors, the principal Instrument for Surveying in the West-Indies.

Gunter's, or Four-Pole Chains.

Off-set Staves.

Water-Levels, of all Sorts.

Artillery Levels.

Gunners Levels.

Levelling

Levelling Staves.

Plotting Scales.

Sets of feather-edg'd Scales.

Hair Scales.

A new-improv'd Pantographa, for the ready and exact Reduction, or copying of Designs, Schemes, Prints, &c.

Pedometers, something like a Watch ; by which the Way may be measured in Walking.

Measuring Wheels, for Surveying of Lands.

Way-Wifers, for Coaches.

Way-Wifers, of a curious Contrivance, for Chaises.

Gunners Quadrants.

Surveying Quadrants, made of Brass, or Wood, &c.

NAVIGATION *Instruments.*

Gunter's Scales.

Sliding Gunters.

Davis's Quadrant.

Hadley's Reflecting Quadrant.

Mr. Smith's Reflecting Quadrant.

Mr. Smith, Capt. Middleton, and Capt. Harrison, improv'd.

Azimuth Compass.

The Common Azimuth Compass.

Mariners Compasses, either for the Binacle or Cabin.

Noctur-

Nocturnals.

Plane Scales.

Sinical Quadrants.

Telescopes of a new Contrivance, with six
Glasses,

Telescopes for Day or Night.

Prospect and Spy Glasses.

Navigation Books, and Charts.

INSTRUMENTS, *for shewing the
Motion, Attraction, Weight, and Equili-
brio of BODIES, &c.*

A Machine, and Glass Planes, for the
Drop of Oil of Oranges.

Two Planes in a Frame, to be set in a Ves-
sel of tinged Liquor.

Capillary Tubes, and Apparatus.

A Strong Ballance, graduated, for explain-
ing the Properties of Leavers; in which the
Power, Resistance, and Point of Suspension,
are moveable, and may be readily placed in
any given Proportions,

An Instrument and Apparatus for three
Leavers.

An Axis in Peritrochio.

A Double Cone, that runs up an inclined
Plain; which is two Rulers so dispos'd, as to
be inclin'd to each other, and to the Horizon,
which double inclination may be varied as
the Experiment requires.

A little Carriage, and its Appendages, for shewing the Advantages great Wheels have over little ones; and that in all Sorts of Roads, as Clay, Gravel, Sand, Pavements, &c.

A Glass Globe, fixed to a double Axis, which may be whirl'd with any Degree of Velocity, both in a vertical and horizontal Direction.

INSTRUMENTS *for Experiments on Motion, Weight, and Equilibrio of FLUIDS.*

A Trough lin'd with Lead, with a Cock, for several Hydrostatical Experiments.

Several Tubes, bent in different Forms.

Hydrostatical Bellows.

A Glass Tube, with a Bladder fix'd at one End.

A Glass Bucket and Wooden Cylinder.

A Hydrostatical Ballance, of a new Contrivance.

An hollow Glass Ball, with a Cock to it, to prove that Water weighs Water.

Areometers, or a Liquor-Proof of Glass.

Hydrometers, of Brass or Copper.

A Cylindrical Glass Vessel, and hollow Images in Glass, that may be moved by Compression, without being perceived by the Spectators.

A Model of the Diving-Bell, and Apparatus.

A Common Syphon, and others of different Forms.

A Double Syphon.

A Syphon, whose Arms are moveable by a Joint.

A Tantalus Cup, of several Fashions.

Glass Models of Sucking } Pumps, with or without
Forcing } Air-Vessels, which shew
and Lifting } the Reasons of Fire-Engines playing with a continual Stream.

A large Fountain by compress'd Air, with Variety of Jet d'Eaux; to which also may be applied an Apparatus for shewing the various Curves that are made by Projectiles.

INSTRUMENTS for *Pneumatical Experiments*

A small single Barrel Air-Pump.

A large double Barrel, standing, or tall Air-Pump, and Apparatus.

A double Barrel Table Air-Pump.

An Apparatus for the Spirits of Fire in the Vacuo.

A Double Transferer, for communicating a Vacuum from one Receiver to another.

Two Brass Hemispheres, with a Stop-Cock and Rings.

A Wind-Gun, with a condensing Syringe in its Stock, having a Magazine of six Balls, from which one Ball at a Time may be put into the Barrel, without letting the air escape;

B

and

and one charging it with Air is sufficient to the Discharge of all the Balls.

Capillary Tubes of various Sizes.

Thermometers for measuring the Increase or Decrease of the Heat and Cold of the Air.	} of Spirits of Wine, by Sir Isaac Newton, by Farenheits, by Reaumers, by D. Lisle, &c. &c.	} Standard either of Spirits, Oyl, or, Mer- cury.
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Barometers of all Sorts.

An Apparatus for an artificial Storm.

OPTICAL INSTRUMENTS.

Spectacles ground on Brass Tools, set in Silver, Tortoiseshell, Horn, &c.

Reading Glasses, set in Variety of curious Frames,

Concaves for short-sighted Persons.

Prospect Glasses of all Lengths.

Opera Glasses.

Diagonal Prospects.

Telescopes of all Lengths.

Newtonian Reflecting Telescopes.

Gregorian Reflecting Telescopes,

Microscopes, Wilson's.

————— Opake.

————— Double.

————— Solar Apparatus to ditto.

Camera Obscuras of all Sorts.

IN-

INSTRUMENTS for Experiments on Lights and Colours.

An Helioſtata, or Machine for directing the Sun's Rays into a dark Chamber, which of itſelf directs the Mirrour in a proper Manner, to caſt the Rays in the ſame Line for ſeveral Hours together.

Solid Glaſs Priſms, mounted on Feet, by which Means they may be raiſed, depreſſed, inclined, or turned upon their Axis.

Priſms of ſolid Glaſs, not mounted.

Several Glaſs Lens, mounted in Frames, on Feet.

A large Paper Screen for Experiments on the Priſms, and the Solar Microſcope.

Concave }
Convex } Mirrours of all Sizes.

Metalline }
Cylinders, }
Cones, } with deformed Pic-
Pyramids, } tures
Octagons, }

Magick Lanthorns.

Pictures to ditto.

INSTRUMENTS, &c. for Experiments on Electricity, &c.

Natural Armed Loadſtones,

Artificial Loadſtones.

A Compaſs Dial.

A Long Needle, in oblong Box.

A Sea Compass.

A large Glass Tube, open at both Ends.

Another that may be exhausted.

A Glass Globe for Whirling.

Another that may be exhausted, and applied to the Whirling Machine.

Glass Plates.

Several little Stands.

A solid Stick of Sealing-Wax, of proper Length.

A Tube of ditto.

A Stick of Brimstone.

A Cone of ditto, covered with a Glass.

A little Amber Ball, and another of Coral.

Several little Ivory Cups.

¶ A Metal Pyramid for the Communication of Electricity.

• A Suspender, furnished with with Ribbons of different Colours.

A Cake of Rosin and Gum Lac.

A very strong Packthread String, with Bells for communicating Electricity.

Silken Lines for the same Purpose.

Instruments for Astronomy, Geography, &c. Globes, coelestial and terrestrial, of all Sizes, neatly fitted up, viz. of 3, 9, 12, 17, and 28 Inch Diameter, from the latest Observation.

Armillary Spheres, of any Size.

Large Astronomical Quadrants, fitted with a Telescope for taking the Declination of the Sun, Moon, and Stars, in the Meridian.

Transit

Transit Instruments, for determining their Right Ascensions.

Equal Altitude Instruments.

Telescopes fitted with a Micrometer.

Helioscopes, or Instruments for observing the Spots in the Sun.

Meridian Telescopes, for correcting the Motion of a Clock or Watch.

A new Universal Sun-Dial on a Pedestal.

Horizontal Sun-Dials, of various Kinds.

Sutton's or Collins's Quadrants.

Gunter's Quadrants, &c.

Two Hemispheres on the Plane of the Ecliptick, containing all the Stars in Mr. Flamsteed's Catalogue.

Orreries, or Planetariums, 12 Inches Diameter, which shews the Motion of the Earth and Moon about the Sun.

Orreries about two Feet Diameter, which shews the Motion of the Earth and Moon together, with the Inclination of the Moon's Orbit; the Retrogradation of the Nodes; the annual and diurnal Motion of the Earth, and Motion of the Sun round his Axis, &c.

A Planetarium, about two Feet Diameter, with all the Motions of the last Number, and the Addition of the two Inferior Planets, Mercury and Venus, the former having its annual, and the latter both its annual and diurnal Motions: By this Instrument the Situation of the Planets, with Respect to the Earth at different Times, as they appear direct Stationary or Retrograde, are plainly visible; as is also the
Eclipses

Eclipses of the Sun and Moon, and the Vicissitudes of the Seasons, &c.

A Planetarium of two Feet and a half Diameter, with all the Properties of the two foregoing Numbers, and the Addition of the three Superior Planets, Mars, Jupiter, and Saturn, with their annual Motions.

A Planetarium of about three Feet and a half Diameter, handsomely ornamented, containing all the Particulars of the three foregoing Numbers, and the Addition of the diurnal Motions of Mars and Jupiter; together with the Motions of all the Secondary Planets round their respective Primaries, in their proper Periods, &c.

All the Planetary Machines are so constructed, as to render all the Phenomena (they are intended to demonstrate) very easy and intelligible.

The famous Glass-Sphere of the Rev. and Learned Dr. LONG's Invention, which exhibits, at one View, both the real and apparent Motion of the Heavens.

N.B. Most Money for all Sorts of Mathematical, Philosophical, and Optical Instruments.

F I N I S,